FIELD INVESTIGATION MANUAL

Phytotoxicology Section-Air Resources Branch

Technical Support Sections-NE and NW Regions

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Ministry of the Environment
Ontario

The Honourable
Keith C. Norton, Q.C.,
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CHAPTER 2: GLOSSARY OF TERMS

The 100 terms in this glossary have been selected from a glossary which was prepared by the Pollution Damage on Plants Committee of the American Phytopathological Society.

Abaxial	-	facing away from the axis of stem; usually refers to the under surface of a leaf blade.
Abscission	-	the natural separation of flowers, fruit, and leaves from plants by the development and subsequent disorganization of a separation layer.
Acid aerosol	-	acid droplets, generally less than 1 micron diam., suspended in air.
Acid gas	-	the anhydrous gaseous phase of an acid, e.g. - hydrogen fluoride.
Acid rain	-	rain that contains as principal components the hydrolyzed end products from oxidized sulfur, nitrogen, and/or halogen compounds.
Acute injury	-	injury, usually involving necrosis, which develops within several hours to a few days after a short-term exposure to a pollutant, and expressed as fleck, scorch, bleaching, bifacial necrosis, etc.
Adaxial	-	facing toward the stem axis; usually refers to the upper surface of a leaf blade.
Additive effects	-	the combined effects of more than one pollutant acting simultaneously or in succession to give a total plant response equal to the sum of the independent effects.
Aerosol	-	a cloud of solid particles and/or liquid droplets smaller than 100 u diameter, suspended in a gas.
Air quality standards	-	air pollutant concentrations which cannot legally be exceeded during fixed time intervals within specified geographic areas.
Ambient air	-	air surrounding a given locus; the outside air.
Amphistomatous	-	a leaf with stomates on both the adaxial and abaxial surfaces.
Anhydride	-	a chemical compound derived by the extraction of a molecule of water from the original molecule.
Antagonism	-	when the combined effect of two or more pollutants is less than the sum of their independent effects; the antonym of synergism.

Antioxidant Antiozonant - a chemical that detoxifies or decreases the oxidizing effects of ozone or other oxidants; e.g. - ascorbic acid.

Banding - foliar symptom characterized by a limited zone of necrotic or discolored tissue traversing the leaf, e.g. - the band on petunia leaves injured by PAN.

Bifacial necrosis - death of plant tissues extending from the adaxial to the abaxial leaf surface.

Bioindicator - plant species, varieties, or cultivars sufficiently sensitive to a specific pollutant to make them useful as indicators for the presence of that pollutant.

Bronzing - a brown discoloration that usually appears on the abaxial surface of leaves, and is often an advanced stage of the silvering or glazing typical of injury by PAN and other oxidants.

Chlorosis - a disease condition in green plants, marked by yellowing or blanching.

Chlorotic dwarf of white pine - an abiotic disease of Pinus strobus L. characterized by reduced growth, chlorosis and mottling of the needles, and premature abscission of all but current needles. Ozone and sulfur dioxide have been implicated as causal agents.

Chronic injury - injury which develops only after long-term or repeated exposure to an air pollutant and expressed as chlorosis, bronzing, premature senescence, reduced growth, etc.; can include necrosis.

Damage - a measure of the decrease in economic or aesthetic value resulting from plant injury by pollutants.

Deciduous - falling off or shed at the end of a growing period or season.

Deliquesce - to dissolve gradually and become liquid by absorbing moisture from the air.

Desorption - the release of a substance which has been taken into another substance by a physical process or held in concentrated form upon the surface of another substance; the reverse of absorption or adsorption.

Dichotomous - dividing in succession into parts; showing a dual arrangement.

Distal - farthest or most remote from the median line of the body, from the point of attachment, or from the origin; peripheral (cf. proximal).

Dose - a measured concentration of a toxicant for a known duration of time (concentrations per unit time) to which a receptor is exposed.

Dry sepal	-	a disease of orchids caused by ethylene and characterized by collapsed lesions and necrosis of the sepals.
Epidemiology	-	a science dealing with the factors involved in the distribution and frequency of a disease process in a population of plants or animals.
Epinasty	-	outward and downward curvature of a plant part, usually leaves.
Fleck	-	white to tan necrotic lesions up to a few millimeters in length or diam. and usually confined to the adaxial surface of leaves; a characteristic response of tobacco to ozone.
Fly ash	-	suspended incombustible or partially incinerated matter carried in the gaseous products of combustion.
Fumigation	-	the natural or controlled exposure of plants to toxic gases or volatile substances.
Glaze	-	(see silvering).
Hidden or "invisible" injury	-	plant injury not characterized by overt symptoms, e.g.- decreased yields, lower quality of plant products.
Hygroscopic	-	readily absorbing and retaining moisture.
Hypertrophy	-	an enlargement or over-growth of an organ or tissue due to an increase in the size of its constituent cells.
Hypostomatous	-	a leaf with stomates only on the abaxial surface.
Injury	-	any change in the appearance and/or function of a plant that is deliterious to the plant.
Intercostal	-	leaf tissue between veins; interveinal.
Isopleth	-	a line on a map connecting points at which a given variable has a specified constant value.
Leach	-	to dissolve out by the actions of a percolating liquid.
Lesion	-	an injury or other circumscribed pathologic change in a tissue.
Marginal necrosis	-	death of tissue at the periphery of a leaf blade
Mean, geometric (Mg)	-	a measure of central tendency for a log-normal distribution; the value of a given set of samples above which 50 percent of the values lie.
Mimicking symptoms	-	symptoms similar to those caused by pollutants, but induced by other abiotic or biotic agents.

Morphology	-	a branch of biology dealing with the structure and form of living organisms.
Mottle	-	irregular, diffuse patterns of chlorotic areas interspersed with normal green leaf tissue.
Mutagen	-	any agent that induces heritable genetic change in living organisms.
Pathogen	-	any biotic or abiotic agent capable of causing disease.
Pathogenesis	-	the production or the mode of origin and development of a disease condition.
Pathology	-	the study of the essential nature of disease, particularly with respect to the structural and functional changes in organs and tissues.
Pesticide	-	any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any insects, rodents, nematodes, fungi, weeds, and other forms of plant or animal life or viruses, (except viruses on or in living man or other animals) which are declared to be pests, and any substance or mixture of substances intended for use as a plant growth regulator, defoliant, or desiccant.
Photochemical smog	-	a combination of photochemical oxidants, smoke, fumes, and aerosols in the polluted atmosphere.
Photosynthesis	-	the formation of carbohydrate from carbon dioxide and water in the presence of chlorophyll and light, in plant tissues.
Porometer	-	a device for determining the degree of stomatal opening in leaves by measuring the resistance of air movement through the tissues, or by measuring the rate of diffusion of water vapor out of the leaf.
PPB	-	parts by weight or volume of pollutant per billion parts by volume of air. (usually refers to volume of pollutant if not so stated).
PPHM	-	parts by weight or volume of pollutant per hundred million parts by volume of air. (usually refers to volume of pollutant if not so stated).
PPM	-	parts by weight or volume of pollutant per million parts by volume of air. (usually refers to volume of pollutant if not so stated).
Predis-position	-	the tendency of non-genetic conditions to affect the susceptibility of plants to a later stress or infection.
Premature senescence	-	an accelerated rate of the normal phenological events, e.g. -early maturation of leaves.

Primary pollutants	-	pollutants which are emitted directly from an identifiable source, e.g. - sulfur dioxide from stacks.
Proximal	-	nearest to the center of the body or the point of origin (cf. distal).
Punctate	-	pertaining to minute spots or depressions in leaves.
Ramet	-	a graft-produced progeny from a single tree.
Resistance	-	the inherent and/or environmentally controlled capacity of plants to prevent or lessen injury by pollutants.
Secondary pollutants	-	pollutants produced in the air by reactions involving primary pollutants and/or other atmospheric constituents; e.g. -oxidants produced by photochemical reactions.
Semi-mature tissue needle blight	-	a disorder of unknown etiology affecting *Pinus strobus* L., characterized initially by internal cell discoloration and collapse in the semi-mature region of needles, followed by eventual needle scorching.
Sensitive	-	a physiological condition of susceptible plants, or particular plant tissues, whereby they are prone to injury by pollutants.
Silvering, silverleaf	-	a symptom of leaves or fleshy tissues caused by the abnormal increase of subepidermal air spaces; often induced by PAN on the abaxial surface of leaves after injury to spongy mesophyll cells.
"Sleepiness" disease	-	a disease characterized by irregular opening or otherwise abnormal development of flowers exposed to ethylene.
Smog	-	(General) a mixture of smoke and fog (London type) - a mixture of coal smoke and fog, containing enough sulfur dioxide to impart chemical reducing properties to the mixture. (Los Angeles type) - a mixture of photochemical oxidants, primary pollutants from petroleum combustion, smoke, and aerosols.
Smoke	-	solid and/or liquid gas-borne particles, often less than 1 micron diam., formed by incomplete combustion of carbonaceous materials and present in sufficient quantity to be visible.
Sorption	-	a process by which one substance takes up and holds the molecules of another substance, as by absorption or adsorption; the process of uptake and retention of gases by plants.

Stipple	-	pigmented spots up to a few millimeters diam., often on the adaxial surface of leaves.
Stomatal conductance	-	the degree to which stomata allow passage of gases, water vapor, or fluids between internal tissues of the leaf and the ambient air.
Stomatal resistance	-	the degree to which stomata impede conductance of gases, water vapor, or fluids between internal tissues of the leaf and the ambient air.
Sublethal dose	-	a dose of a toxicant less than that required to kill cells or tissues.
Suture red spot	-	premature reddening and ripening of a sharply delimited area along the suture line of peach fruits; a symptom of fluoride injury.
Synergism	-	a situation in which the combined action of two or more agents acting together is greater than the sum of the action of these agents separately.
Threshold dose	-	the minimum dose of a pollutant necessary to induce plant injury.
Tipburn, tip necrosis	-	necrosis of apical tissues of leaves; includes only a small percentage of the entire leaf.
Toxicant	-	a substance that kills or injures living organisms by its chemical or physical action, or by altering the environment of the organism.
Transpiration	-	the emission of water vapor from the surface of plant leaves.
Weather fleck	-	flecks which develop on certain varieties of tobacco after exposure to ozone.

CHAPTER 3: EVALUATION OF INJURY OR LOSS

Evaluation of air contaminant effects on vegetation is central to the interpretation of overall losses due to air pollution. To be effective, the evaluation of these effects must be objective, accurate and standardized.

It is beyond the scope of the present chapter to place an economic value on the injury to vegetation or even to provide a means of determining this value. Vegetation may suffer many types of injury due to exposure to various pollutants. Some injury may be readily visible while other types of injury may be difficult to assess.

Injury to vegetation may be considered as a loss in yield (i.e. reduced biomass, reduction of seed crop, etc.) loss in quality (i.e. fleck in tobacco, injury to edible foliage, lowered nutrient content), increased toxic components (i.e. fluoride in forage) or as decrease in aesthetic value (i.e. colour change of foliage, lowered production of flowers, loss of significant species from landscape).

The present chapter will serve primarily as a guide to the evaluation of visible injury and yield and growth parameters.

A Visible Injury Assessment

The accuracy of the assessment of visible injury is directly dependent on the technique used to evaluate the injury. It should be self-evident that plants examined by any sampling technique should be representative of the plants present in the crop (or specified area) under investigation.

In an evaluation of injury, the severity of injury can be evaluated on the basis of:

1. Average percentage of leaf area affected on an entire plant or tree basis
2. Average percentage of leaf area affected on a sample basis
3. Percentage (and location) of leaves affected on a plant
4. Percentage of affected plants in a designated area.

Regardless of the system employed it is imperative that the basis for the evaluation be clearly stated.

Injury ratings can be given in several ways including:

1. Numerical
2. Relative severity
3. Percentage values

Various numerical rating systems are available; however, these are seldom comparable between plant species or evaluators. If these are used, then they should be defined. The case is similar for relative severity ratings. Percentage injury is probably the most appropriate system to be used as it can be directly measured.

Another method is the use of percentage scales or keys which can be compared with injured foliage samples. Percentage injury can be incorporated into both the numerical and relative severity systems. A value in either of these systems will be applied to a range of percentage injury. These ranges which have been altered slightly from those which have been used by staff from the M.O.E. since 1970 are shown below. Examples of typical foliar symptoms within these ranges are presented in Figure 1.

Leaf Injury Rating

Injury Category	% Injury (Area Basis)
Healthy	0
Trace	$>$ 0 - 1
Light	2 - 10
Moderate	11 - 35
Severe	$>$ 35

Symptoms of injury exhibited by foliage can be placed in several main groups depending upon the pollutant involved. These include necrosis, chlorosis, flecking and stippling, glazing or bronzing, anthocyanosis, and particulate deposits. The locations of these injuries on the leaf may be diagnostic,

therefore, the positions of injury should be recorded as being primarily terminal, marginal or intercostal. The percentage of the total leaf area, where the injury symptoms are present, is recorded. Evaluation of chlorosis and anthocyanosis is somewhat subjective and must be compared with the normal color expected for the same type and age of leaf. Particulate evaluation might be achieved by two methods. The first method is to count the number of particles in a given area of the leaf if the number and size of particles is suitable for this approach. In the case of a heavy coating of particulate on foliage, the amount of particulate could be determined by washing a constant number of leaves in a fixed volume of washing solution. If the leaf area is known, and the particulate in the wash solution is analyzed for specific tracer elements, then the particulate loading to the foliage can be computed.

The assessment of injury severity also can be made on the basis of the overall appearance of the plant. This type of rating is most useful in determining long term effects of foliar injury on perennial species. To assist the evaluator in this type of assessment, two classification systems have been developed for use in the field and are described below.

Crown Condition Classification System

For Coniferous And Deciduous Trees

Rating	Description
1	Near perfect specimen tree
2	High quality forest tree with self pruning of shaded branches
3	Tree in good condition, may have 1 or 2 dead branches
4	Tree in fair to moderate condition with 3 or more dead branches
5	Up to one half of crown dead
6	One half to 75% of crown dead
7	75 - 90% of crown dead
8	Over 90% of crown dead, some branches retaining foliage
9	Branches with few live needles/leaves still attached
10	Tree dead

Foliage Retention Classification System

For Coniferous Trees

Rating	Description
1	Foliage retained over 2 years
2	Over 2/3 of 2 year old foliage retained
3	Less than 2/3 of 2 year old foliage retained
4	Less than 1/3 of 2 year old foliage retained
5	Over 2/3 of 1 year old foliage retained
6	Less than 2/3 of 1 year old foliage retained
7	Less than 1/3 of 1 year old foliage retained
8	Only current years foliage retained
9	Less than 2/3 of current year's foliage retained
10	Only 1/3 or less of current year's foliage retained

B Yield and Growth Assessment

One of the most important aspects of assessing the impact of air pollutants on vegetation is to accurately determine the decrease in yield or growth of vegetation exposed to pollutants. An accurate economic impact assessment is directly dependent on the accuracy of the methods used to measure the net changes in vegetation caused by pollutants. The following information is provided as a means of standardizing various yield/growth parameters.

1 Seed Crops

The best overall measure of yield of seed crops is to measure the quantity of seed harvested by normal farm methods (provided that they are done carefully) and divide this quantity by the total crop area. The resulting value is the yield and is usually expressed as bu/A, tonnes/ha, etc. This large-area approach may not be applicable

in certain circumstances of localized sources of contaminants which may affect only a portion of a crop. In this case, small sample plots need to be established over the field in such a manner that both affected and unaffected areas are sampled for comparison purposes. Such sample plots should be selected to show the distribution of affected crop plants with care being taken to minimize the effects of other edaphic variables on crop yield.

As a minimum, it is suggested that not less than six areas are sampled: check area (2), affected area (2), intermediate area (2). All plot locations must be accurately mapped and the sample plots should cover not less than $1 m^2$ in area. The plots should be harvested at maturity and the grain, straw and chaff weighed. A weight measure of a constant number of seeds (100) will also provide information which can be used to calculate seed size and/or the total number of seeds harvested. When these results are reported it should be noted that the yields will be higher than could be expected by the grower due to the greater efficiency of the harvesting procedure compared to normal farm practices.

2 Forage Crops

The best overall measure of yield of forage is to determine the quantity harvested by normal farm methods taking the total crop area into consideration. This can be done by weighing random bales of hay and calculating the total crop weight from the number of bales harvested. Other techniques may be used for forage prepared in other ways. If localized sources of contaminants are involved or if the forage is utilized in the context of a pasture, then biomass sampling techniques can be adapted. Sample locations should be selected using the same technique as outlined in Section B (1). Such sample locations must be accurately mapped and each should cover an area of not less than 1 m x 1 m.

Plots are harvested at normal harvest time. The fresh and dry weights of samples are determined and samples may be processed for various additional analyses. The data are compiled to determine the net impact of the localized pollutant on yield.

3 Vegetable Crops

The variety of different vegetable and specialty crops requires that each type of crop be measured according to its own yield parameters. These can be various combinations of the following parameters:

Yield Parameter	Unit Basis
Number of individual fruits or vegetables	Per plant
Total weight (fresh or dry basis)	Per length of planting row
Volume (litres, quarts)	Per unit crop area.

4 Growth Parameters

a) Plant Height

Plant height is measured from ground level to tip of the uppermost meristem.

b) Plant Weight

Fresh weight measurements should be taken immediately following field collection to prevent any changes due to desiccation.

Dry weight measurements should be taken after plant tissues have been oven dried at 105°C for a period of 24-48 hours. In some cases, air dry rather than oven dry weights may be measured to generate yield data on a 12-14% dry matter basis for comparison with published, adjusted crop yield values. Sample weights can be taken from either whole plants or portions of plants (i.e. leaf, fruit, roots, etc).

c) Leaf Size

Leaf length is measured from the junction of the petiole and leaf lamina along the main vein to the tip of the leaf. Several methods can be employed in measuring leaf area:

planimeter	photocopy	L-cor leaf area meter
dot grid	imprints	
mechanical scanner	traversing	

d) Shoot Length

Shoot length measurement should be taken from the previous season's growth or the start of the current season's growth (terminal bud scar) to the tip of the meristem.

e) Stem Diameter (D.B.H.)

The measurement of diameter at breast height (1.5 m) of the trees should be made in the same way as when cruising the forest or sample plot. If the initial sample plot measurements were made with the diameter tape, it is advisable to use the tape again when measuring the trees at later times. The diameters are usually measured to the nearest millimeter.

When using calipers, the question arises as to whether one or two diameters should be measured. Again, the procedure should agree with the one applied when making the inventory. If the tree was measured only once and from the uphill side, it should be measured again in the same place. It is convenient to paint bands around trees to be measured at breast height levels such that subsequent measurements will always be made at the same position. When measuring forked trees, the stems that fork below D.B.H. are considered to be two separate trees. Figure 2 illustrates suggested methods for maintaining consistency in obtaining diameter measurements.

f) Annual Ring Width

Increment borers must be handled with great care, if undue breakage and wear are to be avoided. The directions which are supplied with a new instrument should be followed closely. Somewhat abbreviated, these directions read as follows:

"The borer is grasped in one hand, at the middle of the handle. It is of the utmost importance that the boring be started at

right angles to the surface at the point where the sample is to be taken; otherwise, the threads will be subjected to bending stresses, and may be broken. The harder the wood of the tree, the greater the danger of breaking the threads. The borer must be pressed firmly into the bark and slowly turned until the screw has gripped the wood. Then without exerting further pressures, turn quickly until the desired or greatest possible depth is reached. Insert the extracting needle between the core and the inside wall of the auger with the serrated edge against the core and then give the borer a half turn backward to break off the core at the cutting edge. The needle and core may now be removed.

... Guard the cutting edge of the increment borer very carefully, since a perfect cutting edge is essential to the production of smooth cores. A small nick in the cutting edge will scratch the core and make it difficult to trace the rings. Oil the borer frequently inside and out to prevent rusting; when boring hard woods, always grease the screw well since this precaution materially lightens the work.

... If the borer becomes encrusted with resin or gum, this should be removed with turpentine. Always keep increment borer well cleaned and oiled".

It has generally been considered that the holes should be plugged to avoid the entrance of rot producing fungi; however, in recent investigations the need of this practice is questioned.

g) Stem Analysis

Stem analysis is a technique which enables an investigator to examine how the growth of an individual tree has changed with time. The required measurements can be taken from a standing tree with an increment borer and diameter tape, however; this has obvious disadvantages. The usual procedure is to fell the tree, cut it into sections and remove disks from the sections for

detailed measurements in a field camp or laboratory. It is, naturally, a destructive sampling method and therefore may not be applicable in many study situations. Stem analysis is conducted on a single tree with the results intended to be representative of a local population; therefore care should be taken to select a tree which is as close as possible to the average height and age of the forest stand being studied. If recent timber cruise data are not available then average stand height (of the study species) can be quickly determined in the field using a clinometer or other height measuring instrument. The sten analysis field procedure is quite straight forward, as follows:

1. Select a tree of average stand characteristics and fell at a 30 cm stump height using a cut at right angles to the bole.

2. De-limb and remove all debris from the work site. This takes extra time but minimizes the chance of accidents while using power equipment.

3. Determine and record species, diameter breast height (DBH) to the nearest 10th cm and total height to the nearest 10th m.

4. Cut the stump at the root collar, or 0 height, and determine the number of years to reach stump height (= # rings at 0 ht. - # rings at 30 cm stump cut) and the total age of the tree.

5. Decide on the length of tree sections to be cut; 1 m intervals are most frequently used, although longer and irregular lengths can also be applied, particularly when sectioning hardwoods or very tall trees. Mark the desired intervals on the felled tree starting at the 30 cm cut and progressing right to the tree top. Cut the sections at right angles to the bole at each marked segment and label immediately. Remove a disk from the bottom of each section including the 30 cm stump and the less than 1 m top, label immediately, and measure and record the

length of the tree tip. The tree disks can now be removed from the site and the measurements concluded at a field camp or laboratory.

6. Determine the mean (inside bark) diameter of each disk. An accepted method of determining mean diameter is the average of two diameter measurements taken at right angles to each other.

7. Determine the mean (inside bark) radius of each disk. This is simply ½ of the mean diameter. Mark the mean radius on the cleanest face of each disk. It is along this mean radius line that all ring counts and growth measurements are made.

8. It is often necessary to prepare the disks so that the annual rings are easier to distinguish. A belt sander using a coarse followed by a med/fine sanding belt is most appropriate for removing the saw ridges and smoothing the wood face. This also exposes the entire cross section of the disk to examination. However if this is not available then a V shaped notch cut with a razor knife along the mean radius line produces a clean path of observation. Depending on the tree species the growth rings may still not be clearly visible, as is essential for accurate measurement. Rubbing glycerine or petroleum jelly along the observation radius usually enhances the rings sufficiently to allow for examination with the naked eye, hand lens, or low power microscope.

9. Along the mean radius of each disk count and record the number of annual rings from the cambium in towards the pith. Mark every 5th year (from the cambium). Although 5 year growth intervals are most frequently used a 10 year or longer span may be more practical if the tree is particularly old.

10. On each disk measure and record (in mm) the distance along the mean radius from the pith to each 5 year interval. The

fractional portion, that less than the established interval closest the pith, will always be recorded first.

With data obtained from stem analysis it is possible to construct ht/age, dia/age and if required ht/dia curves for specific trees. It is also possible to determine the wood volume of any section of the tree, the total volume and more importantly the volume of wood produced at any given period of time in the tree's history. Although the procedures for the various volume calculations are quite straight forward the format for the data set-up can be quite lengthy and need not be discussed in detail here. For complete information on growth and volume measurements refer to Husch, Miller and Beers "Forest Mensuration" 1972 Ronald Press Co.

The section volumes which are of the same age are added up to obtain the volume of the total tree and converted to cubic meters to the closest .001 m^3.

The length of the sections are all 1 m or 100 cm except that of the first section which is .3 m or 30 cm and that of the youngest age class. This youngest age class section is assumed to be conical in shape, with a basal area equal to that of a circle having a radius the distance from the outer ring to the pith.

5 Quality Parameters

In all cases where quality of crop produce or wood products is to be evaluated, the standards for grading to be applied will be those developed for individual crops by the Ontario Ministry of Agriculture, the Canada Department of Agriculture, or the Ontario Ministry of Natural Resources.

6 Reproductive Potential

The stress of air contaminants on vegetation may be manifested in reduced yield of reproductive parts of the plants (fruits, seeds) or in

reduced viability of the seed. The consequence of this latter effect would be a lowering of the value of commercial crops in quality and/or quantity which could lead to shifts in species composition in natural or uncultivated areas.

In the absence of any background information, many plant seeds may be tested by germinating them in petri dishes. It is suggested that conditions for initial tests include placing several lots of 25 seeds in petri dishes lined with filter paper. Approximately 2 ml distilled water are added to the dishes which are incubated in the dark at 25°C. The dishes are examined periodically to evaluate germination and to ensure that the filter papers have not dried out. Additional water may be added periodically as required.

Germination is scored if the length of the emerging radicle is equal to the diameter of the seed. Additional tests might include measurement of the length of primary roots after different periods of time.

If the above test method is found to be unsatisfactory, the various conditions may be modified to suit the particular conditions involved. Consideration should be given to scarification or stratification of seeds as required.

Figure 1: Foliar Injury Rating Key

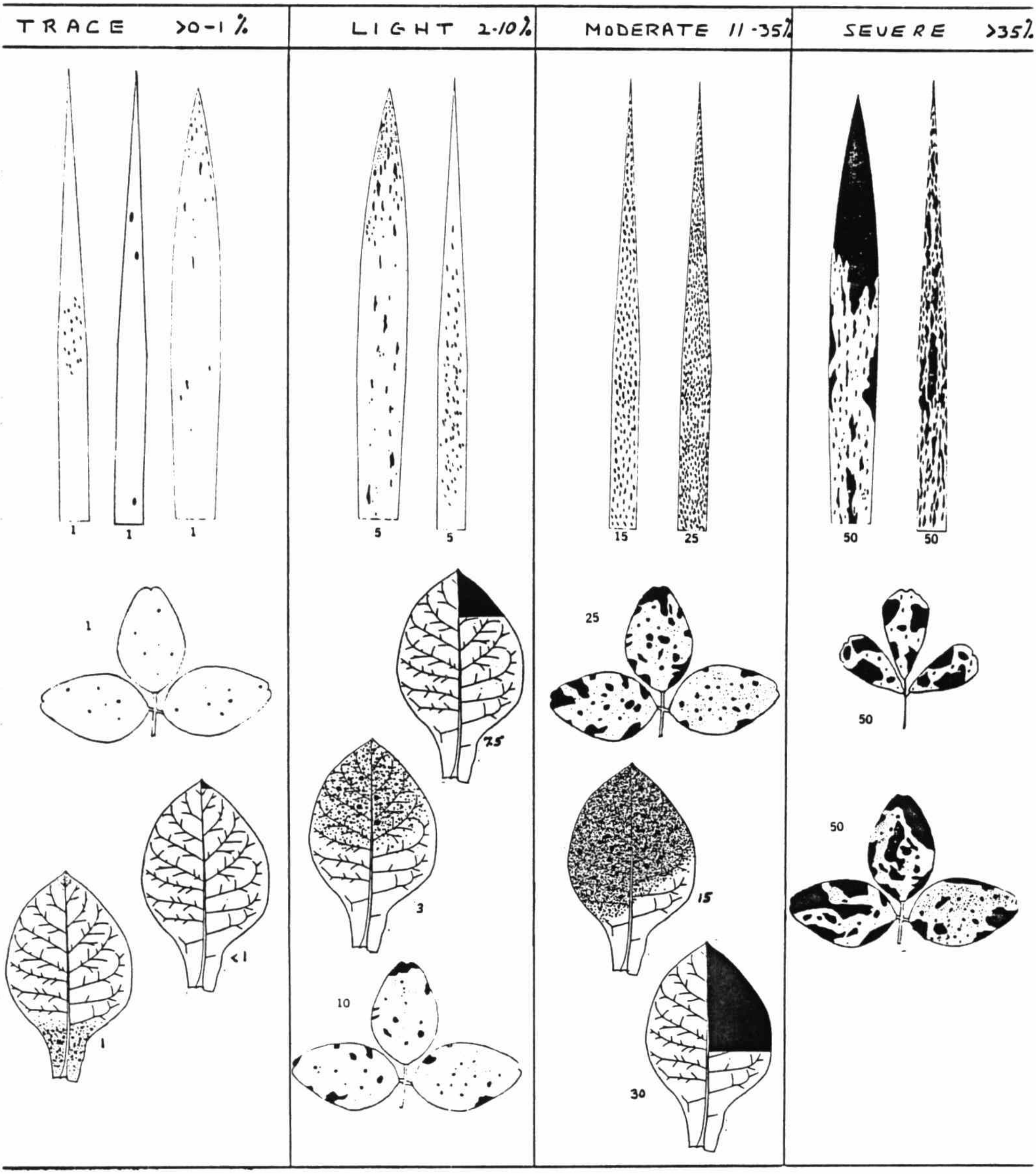
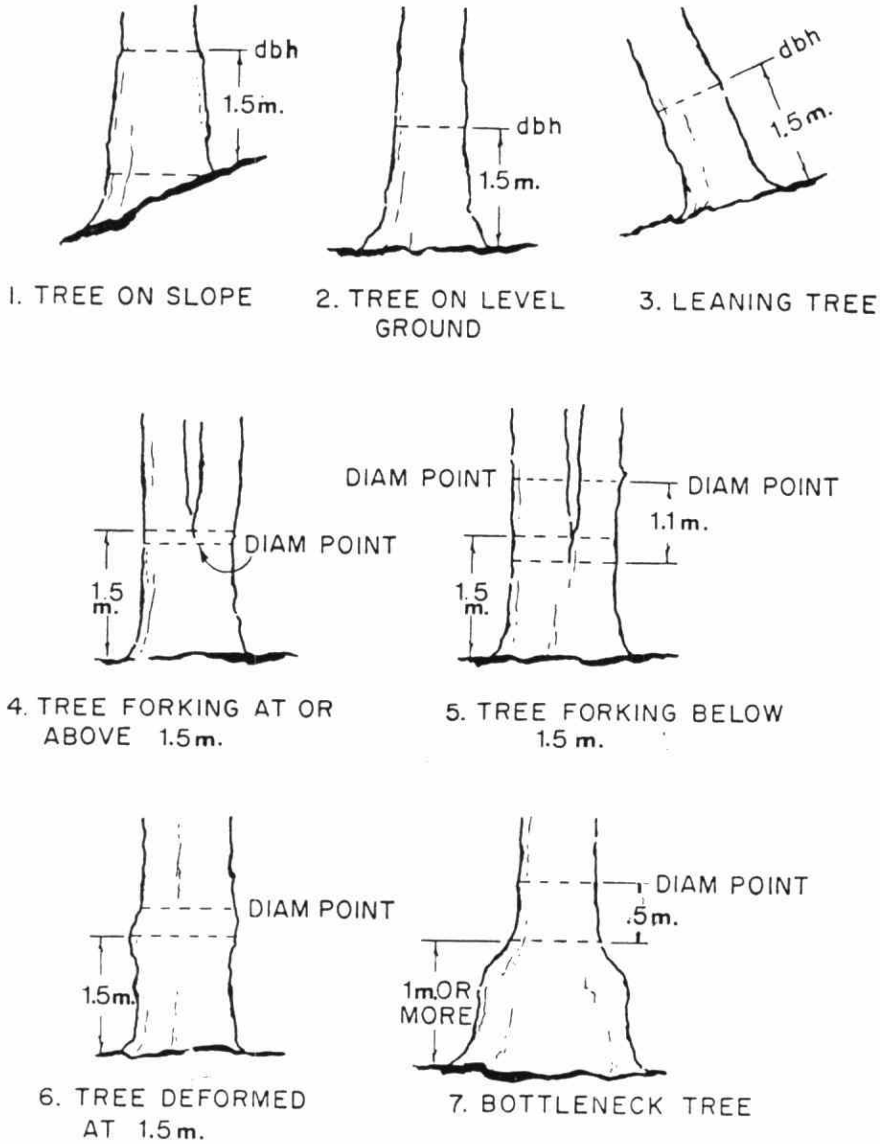


Figure 2: <u>DBH Measurement Technique</u>



Points of dbh measurement for sloping ground or irregular tree stems. *Reprinted from the "Forest Survey Handbook,"* 1964.

CHAPTER 4: PLANT RESPONSE TO AIR POLLUTANTS

A Symptom Descriptions

By careful observation of an injured plant or leaf, it is usually possible to differentiate between the symptoms induced by a pollutant and those associated with a host of other biological agents or environmental factors. In general, our primary concern is with those pollutants in the gaseous phase as these enter the leaf through the stomata; however, there are many other contaminants which can cause injury through deposition in a liquid, aerosol or solid phase (particulate). The table below describes in a very generalized manner the common symptom types for many of the pollutants which are encountered during Phytotoxicology field investigations.

Typical Foliar Injury Symptoms for Several Air Pollutants

Pollutant	Typical Acute Foliar Injury Symptoms
Ammonia	Initially leaves display cooked green appearance. Broadleaf tissues collapse to form irregular dark or discoloured marginal or intercostal areas, whereas grasses often show reddish, interveinal necrotic streaking or dark upper surface discoloration.
Arsenic	Predominately marginal necrosis varying from light tan to brown-black in color. On Manitoba and silver maple the leaf margins tend to curl inwards.
Boron	Most common symptoms include irregular dark intercostal necrotic lesions with occasional marginal necrosis, severe leaf distortion, and twig dieback; leaves frequently have a desiccated or burned appearance.
Chlorine	Similar to SO_2 symptoms. Intercostal chlorosis and necrosis followed by bleaching of necrotic tissue. Silvering of upper leaf surface has been noted.
Fluoride	Injury is primarily tip and marginal. Necrotic areas are often reddish-brown, separated from healthy areas by a sharply-defined band; e.g.

	apricot, plum, white pine. Necrotic areas occasionally blackened; e.g. silver maple. Monocot leaves show streaked or banded necrotic areas; e.g. sweet corn.
Mercury	General chlorosis of leaf. At high concentrations, brown spotting on leaves; flower parts blacken; e.g. rose, carnation.
Nitrogen Dioxide	Similar to SO_2. Large irregular water-soaked areas later bleach to a brown or tan color. Lesions are mainly intercostal; e.g. tobacco, pinto bean, hibiscus.
Ozone	Small irregular fleck or stipple-like lesions on upper leaf surface; can be light or dark; lesions often collapse, giving pitted appearance to leaf; e.g. tobacco, ash, grape. Coniferous needles show stipple-like chlorotic spots; e.g. white pine.
Sulphur Dioxide	Woody plants: brown or reddish-brown intercostal necrosis; small to large irregularly-shaped lesions. Herbs: marginal or intercostal necrosis; necrotic areas bleach to ivory or tan color, e.g. alfalfa, buckwheat.

B Susceptibility Ratings

Plant susceptibility ratings for the most common and best documented pollutants (F, O_3, SO_2, NH_3, HCl, Cl_2) are presented separately in a format which attempts to show the range of plant response over the three main categories (susceptible, intermediate, resistant).

FLUORIDE

Susceptibilities of Selected Plants to Fluoride

Plant Species	Susceptible	Intermediate	Resistant
Alder (*Alnus* spp.)			—
Alfalfa (*Medicago sativa* L.)		—	—
Apple (*Pyrus Malus* L.)		—	—
Apricot, Chinese and Royal (*Prunus armeniaca* L.)	—		
Apricot, Moorpark and Tilton (*Prunus armeniaca* L.)	—	—	
Arborvitae (*Thuja* spp.)			—
Ash, Green (*Fraxinus pennsylvanica* var. *lanceolata* Borkh.)		—	
Ash, Modesto (*Fraxinus velutina* Torr.)			—
Asparagus (*Asparagus* spp.)			—
Aspen, Trembling (*Populus tremuloides* Michx.)		—	
Aster (*Aster* spp.)	—	—	
Azalea (*Rhodoendron* spp.)	—	—	—
Barberry, Japanese (*Berberis thunbergii* L.)			—
Barley (young) (*Hordeum vulgare* L.)	—		
Barley (mature) (*Hordeum vulgare* L.)		—	

Fluoride (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Bean, Snap (*Phaseolus vulgaris* L.)			—
Birch, Cutleaf (*Betula pendula* var. *gracilis* Roth.)			—
Birch, White (*Betula papyrifera* Marsh.)			—
Blackberry (*Rubus* spp.)			—
Blueberry (*Vaccinium* spp.)	—		
Bridalwreath (*Spiraea prunifolia* Sieb. & Zucc.)			—
Burdock (*Arctium* spp.)			—
Cabbage (*Brassica oleracea* L.)			—
Carrot (*Daucus Carota* L.)			—
Cauliflower (*Brassica oleracea* L.)			—
Celery (*Apium graveolens* L.)			—
Cherry, Bing and Royal Ann (*Prunus avium* L.)			—
Cherry, Choke (*Prunus serrulata* Lindl.)		—	
Cherry, Flowering (*Prunu virginiana* L.		—	
Chickweed (*Stellaria media* (L) Cyrillo)		—	—
Chrysanthemum (*Chrysanthemum* spp.)	—	—	
Clover, Crimson (*Trifolium incarnatum* L.)			—
Clover, Sweet Yellow (*Melilotus officinalis* Lam.)		—	

Fluoride (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Corn, Sweet (*Zea Mays* L.)	—	—	
Cotoneaster (*Cotoneaster* spp.)			—
Crabgrass (*Digitaria sanguinalis* Scop.)	—		
Crocus (*Crocus* spp.)	—		
Cucumber (*Cucumis sativus* L.)			—
Currant (*Ribes* spp.)		—	—
Dahlia (*Dahlia* spp.)		—	—
Dock (*Rumex* spp.)			—
Dogwood (*Cornus* spp.)		—	—
Eggplant (*Solanum melogena* L.)		—	—
Elderberry (*Sambucus* spp.)			—
Elm, American (*Ulmus americana* L.)			—
Elm, Chinese (*Ulmus pumila* L.)			—
Euonymus (*Euonymus* spp.)			—
Fir, Douglas (*Pseudotsuga menziesii* Franco)	—		
Fir, Grand (*Abies grandis* (Dougl.) Lindl.)		—	
Firethorn (*Pyracantha* spp.)			—
Forsythia (*Forsythia* spp.)			—

Fluoride (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Geranium (*Geranium* spp.)		—	
Gladiolus (*Gladiolus* spp.)	—		
Goldenrod (*Solidago* spp.)		—	
Goosefoot, Nettle-leaf (*Chenopodium* spp.)		—	
Grape, Concord (*Vitis labrusca* L.)		—	
Grape, European (*Vitis vinifera* L.)	—		
Grapefruit (*Citrus paradisi* MacF.)		—	
Hollyhock (*Althea rosea* Cav.)			—
Honeysuckle (*Lonicera* spp.)			—
Impatiens (*Impatiens* spp.)		—	
Iris (*Iris* spp.)	—		
Jerusalem Cherry (*Solanum Pseudo-Capsicum* L.)	—		
Johnson Grass (*Sorghum halepense* (L) Pers.)		—	
Juniper (*Juniperus* spp.)			—
Lambs'-Quarters (*Chenopodium album* L.)	—	—	
Larch, Western (*Larix occidentalis* Nutt.)	—		
Lemon (*Citrus* spp.)		—	
Lilac (*Syringa vulgaris* L.)		—	

Flouride (Cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Linden, American (*Tilia americana* L.)			—
Linden, Little-leaf (*Tilia cordata* Mill)		—	
Locust, Black (*Robinia Pseudo-acacia* L.)			—
Locust, Honey (*Gleditsia triacanthos* L.)			—
Maple, Hedge (*Acer campestre* L.)		—	
Maple, Manitoba (*Acer Negundo* L.)	—		
Maple, Norway (*Acer platanoides* L.)		—	
Maple, Silver (*Acer saccharinum*)	—	—	
Mock-Orange (*Philadelphus* spp.)			—
Mountain Ash, European (*Sorbus Aucuparia* L.)	—	—	
Mountain Laurel (*Kalmia latifolia* L.)			—
Mulberry, Red (*Morus rubra* L.)		—	
Narcissus (*Narcissus* spp.)		—	
Nightshade (*Solanum nigrum* L.)			—
Oak (*Quercus* spp.)			—
Oats (young plants) (*Avena sativa* L.)		—	
Oats (mature plants) (*Avena sativa* L.)		—	—
Oregon Grape (*Mahonia repens* Don)	—		

Fluoride (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Pea, Garden (*Pisum sativum* L.)			—
Peach (fruit) (*Prunus Persica* (L) Batsch.)	—		
Peach (foliage) (*Prunus Persica* (L) Batsch.)		—	
Pear (*Pyrus communis* L.)			—
Peony (*Paeonia* spp.)		—	
Pepper, Bell (*Capsicum frutescens* L.)		—	—
Petunia (*Petunia* spp.)			—
Pigweed (*Amaranthus retroflexus* L.)		—	
Pines: Eastern White, Lodgepole, Scotch, Mugo, Ponderosa (*Pinus strobus* L., *P.contorta* Dougl., *P.sylvestris* L., *P.mugho* Turra., *P.ponderosa* Laws.)			
(young needles)	—		
(old needles)			—
Planetree, London (*Plantanus acerifolia* L.)		—	—
Plantain (*Plantago* spp.)			—
Plum, Bradshaw (*Prunus domestica* L.)	—		
Plum, Flowering (*Prunus cerasifera* Enrh.)		—	—
Poplar, Balsam (*Populus balsamifera* L.)			—
Poplar, Carolina (*Populus canadensis* Moench.)		—	—
Poplar, Lombardy (*Populus nigra* var. *italica* Du Roi)		—	—

Fluoride (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Potato, Sweet (*Ipomoea batatas* L.)	—	—	
Potato, White (*Solanum tuberosum* L.)			—
Privet (*Ligustrum* spp.)			—
Prune, Italian (*Prunus domestica* L.)	—		
Purslane (*Portulaca oleracea* L.)			—
Rasberry, Red (*Rubus idaeus* L.)		—	—
Rhododendron (*Rhododendron* spp.)		—	
Rose, Tea (*Rosa odorata* Sweet.)		—	
Russian Olive (*Eleagnus angustifolia* L.)			—
Rye (young plants) (*Secale cereale* L.)		—	
Rye (mature plants) (*Secale cereale* L.)		—	—
St. Johns'-wort (*Hypericum perforatum* L.)	—		
Serviceberry (*Amelanchier* spp.)	—	—	
Smartweed (*Polygonum* spp.)	—	—	
Sorghum (*Sorghum vulgare* Pers.)	—	—	
Soybean (*Glycine Max* (L) Merr.)		—	—
Spinach (*Spinac ia oleracea* L.)		—	—
Spruce, Blue (*Picea pungens* Englm.)	—	—	
Spruce, White (young needles) (*Picea glauca* (Moench.) Voss.)		—	

Fluoride (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Squash, Summer (*Cucurbita pepo* L.)			—
Strawberry (*Fragaria* spp.)		—	—
Sumac, Smooth (*Rhus glabra* L.)		—	
Sumac, Staghorn (*Rhus typhina* L.)		—	
Sunflower (*Helianthus* spp.)		—	—
Sweet Gum (*Liquidambar Styraciflua* L.)			—
Sweet William (*Dianthus barbatus* L.)		—	
Sycamore (*Platanus occidentalis* L.)			—
Tobacco (*Nicotiana Tabacum* L.)			—
Tomato (*Lycopersicon esculentum* Mill.)		—	—
Tree-of-Heaven (*Ailanthus altissima* L.)			—
Tulip (*Tulipa Gesnerana* L.)	—	—	
Violet (*Viola* spp)		—	
Virginia Creeper (*Parthenocissus quinquefolia* Planch.)			—
Walnut, Black (*Juglans nigra* L.)		—	
Walnut, English (*Juglans regia* L.)		—	
Wheat (young plants) (*Triticum* spp.)		—	
Wheat (mature plants) (*Triticum* spp.)		—	—

Fluoride (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Willow (*Salix* spp.)			—
Yew, Spreading Japanese (*Taxus cuspidata* Sieb. & Zucc.)		—	
Yucca (Adams Needle) (*Yucca filamentosa* L.)			—

OZONE

Susceptibilities of Selected Plants to Ozone

Plant Species	Susceptible	Intermediate	Resistant
Alder (*Alnus* spp.)	—		
Alfalfa (*Medicago sativa* L.)	—		
Apricot (*Prunus armeniaca* L.		—	—
Arborvitae (White cedar) (*Thuja occidentalis* L.)			—
Arborvitae (*Thuja orientalis* L.)		—	
Ash, Green (*Fraxinus pennsylvanica* var. *Lanceolata* Borkh.)	—	—	
Ash, White (*Fraxinus americana* L.)	—		
Aspen, Trembling (*Populus tremuloides* Michx.)	—	—	
Azalea (*Rhododendron* spp.)	—		
Barley (*Hordeum vulgare* L.)	—		
Bean (*Phaseolus vulgaris* L.)	—	—	
Beech, European (*Fagus sylvatica* L.)		—	—
Beet, Sugar (*Beta vulgaris* L.)		—	
Beet, Table (*Beta vulgaris* L.)		—	
Begonia (*Begonia* spp.)	—	—	
Bentgrass (*Agrostis palustris* Huds.)	—	—	—

Ozone (Cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Birch, European (*Betula pendula* Roth.)		—	—
Bluegrass, Annual (*Poa annua* L.)		—	
Box, Japanese (*Buxus sempervirens* L.)		—	
Boxelder (*Acer Negundo* L.)	—		
Bridlewreath (*Spiraea* spp)	—	—	
Broccoli (*Brassica oleracea* L.	—	—	
Bromegrass (*Bromus inermis* Leyss.)	—		
Carnation (*Dianthus caryophyllus* L.)	—		
Carrot (*Daucus Carota* L.)	—	—	
Catalpa (*Catalpa speciosa* Warder)	—		
Cherry Bird or Sweet (*Prunus avium* L. var. Lambert)	—	—	
Chrysanthemum (*Chrysanthemum* spp)	—	—	
Clover, Red (*Trifolium pratense* L.)	—	—	
Coleus (*Coleus Bulmei* Benth.)			—
Corn (Field) (*Zea Mays* L.)	—	—	
Corn (Sweet) (*Zea Mays* L.)	—	—	

Ozone (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Cotoneaster (*Cotoneaster* spp.)	———		
Cotton (*Gossypium hirsutum* L.)			———
Crabapple, Siberian (*Malus baccata* Borkh.)	———		
Crabgrass (*Digitaria sanguinalis* (L.) Scop.)	———		
Endive (*Cichorium endivia* L.)			———
Euonymus (*Euonymus* spp.)			———
Fir, Balsam (*Abies balsamea* (L.) Mill.)			———
Fir, Douglas (*Pseudotsuga menziesii* (Mirb.) Franco)			———
Fir, White (*Abies concolor* Hoopes)			———
Forsythia, Lynwood Gold (*Forsythia intermedia spectabilis* Spaeth.)	———		
Fuchsia (*Fuchsia* spp.)	———	———	
Geranium (*Pelargonium* spp.)	———	———	
Grape (*Vitis vinifera* L.)	———	———	
Hemlock *Tsuga canadensis* (L.) Carr.)		———	
Ivy, English (*Hedera helix* L.)			———

Ozone (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Juniper, Pfitzer (*Juniperus chinensis* var. *pfitzeriana,* Spaeth.)	—	—	
Larch, European (*Larix decidua* Mill.)		—	—
Larch, Japanese (*Larix leptolepis* Gord.)	—	—	
Lettuce (*Lactuca sativa* L.)			—
Lilac (*Syringa vulgaris* L.)	—	—	
Lilac, Chinese (*Syringa chinensis* Willd.)	—	—	
Linden, Little leaf (*Tilia cordata* Mill.)		—	—
Locust, Black (*Robinia Pseudoacacia* L.)		—	—
Locust, Honey (*Gleditsia triacanthos* L.)	—	—	
Maple, Silver (*Acer saccharinum*)	—		
Maple, Sugar (*Acer saccharum* Marsh.)			—
Mountain Ash, European (*Pyrus Aucuparia* (L.) Gaertn.)	—		
Muskmelon (*Cucumis Melo* L.)	—		
Oak, Gambel (*Quercus gambelii*)	—		
Oak, Red (*Quercus rubra* L.)		—	

Ozone (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Oak, White (*Quercus alba* L.)	—	—	
Oat (*Avena sativa* L.)	—	—	
Onion (*Allium Cepa* L.)	—	—	
Orchardgrass (*Dactylis glomerata* L.)	—	—	
Pachysandra (*Pachysandra terminalis* Sielo. & Zucc.)			—
Pagoda, Japanese (*Sophora japonica* L.)		—	
Parsley (*Petroselinum hortense* Hoffm.)	—	—	
Parsnip (*Pastinaca sativa* L.)	—	—	
Peach (*Prunus persica* (L.) Batsch.)	—	—	—
Peanut (*Arachis hypogaea* L.)	—		
Pear (*Pyrus communis* L.)		—	—
Petunia (*Petunia hybrida* Vilm.)	—	—	
Pieris (*Pieris japonica* D. Don.)			—
Pine, Austrian (*Pinus nigra* Arnold)	—	—	

Ozone (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Pine, Jack (*Pinus banksiana* Lamb.)	—		
Pine, Pitch (*Pinus rigida* Mill)		—	
Pine, Ponderosa (*Pinus ponderosa* Laws.)	—	—	
Pine, Red (*Pinus resinosa* Ait.)			—
Pine, Scotch (*Pinus sylvestris* L.)	—	—	
Pine, Virginia (*Pinus virginiana* Mill.)	—		
Pine, Eastern White (*Pinus Strobus* L.)	—	—	—
Poplar, Tulip (*Liriodendron tulipifera* L.)	—	—	
Potato, White (*Solanum tuberosum* L.)	—		
Privet (*Ligustrum vulgare* L.)	—	—	
Pyracantha (*Pyracantha coccinea Lalandii* Dipp.)			—
Radish (*Raphanus sativus* L.)	—	—	
Redbud (*Cerc s canadensis* L.)	—		
Rhododendron (*Rhododendron* spp.)	—	—	
Rhododendron (*R. caroliniana* Rehd.)			—
Rhododendron (*R. Mollis* Blume)			—

Ozone (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Rye (*Secale cereale* L.)	—		
Snowberry (*Symphoricarpos albus* (L.) Blake)	—	—	
Spinach (*Spinacea oleracea* L.)	—	—	
Spruce, Black Hills (*Picea galuca* var. *densata*)			—
Spruce, Colorado blue (*Picea pungens* Englm.)			—
Spruce, Norway (*Picea abies* (L.) Karst.)			—
Spruce, White (*Picea glauca* (Moench) Voss)			—
Sumac, Fragrant (*Rhus aromatica* Ait.)	—	—	
Sycamore (*Platanus occidentalis* L.)	—		
Tobacco (*Nicotiana Tabacum* L.)	—	—	
Tomato (*Lycopersicon esculentum* Mill.)	—	—	
Touch-me-not (*Impatiens* spp.)			—
Turnip (*Brassica rapa* L.)	—	—	
Viburnum (*Viburnum burkwoodii* Burk.)		—	—
Virginia Creeper (*Parthenocissus quinquefolia* Planch.)		—	—

Ozone (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Walnut, English (*Juglans regia* L.)	—	—	
Willow, Weeping (*Salix babylonica* L.)	—		
Wheat (*Triticum aestivum* L.)	—	—	
Yew (*Taxus* spp.)			—

SULPHUR DIOXIDE

Susceptibilities of Selected Plants to Sulphur Dioxide

Plant Species	Susceptible	Intermediate	Resistant
Alder, Speckled (*Alnus rugosa* (Du Roi) Spreng.)	—	—	
Alfalfa (*Medicago sativa* L.)	—		
Apple (*Pyrus Malus* L.)		—	
Apricot (*Prunus armeniaca* L.)		—	—
Ash, Red (*Fraxinus pennsylvanica* Marsh.)	—		
Ash, White (*Fraxinus americana* L.)	—		
Asparagus (*Asparagus officinalis* L.)		—	—
Aspen, Large-tooth (*Populus grandidentata* Michx.)	—		
Aspen, Trembling (*Populus tremuloides* Michx.)	—		
Balm-of-Gilead (*Populus gileadensis* Rouleau)			—
Barley (*Hordeum vulgare* L.)	—		
Basswood (*Tilia americana* L.)		—	
Beans, Field (*Phaseolus vulgaris* L.)	—		
Beets (*Beta vulgaris* L.)	—	—	
Beggars-Ticks (*Bidens vulgata* Greene)	—	—	

Sulphur dioxide (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Begonia (*Begonia* spp.)		—	—
Birch, White (*Betula papyrifera* Marsh.)	—		
Birch, Yellow (*Betula lutea* Michx f.)	—		
Birds-Foot Trefoil (*Lotus corniculatus* L.)			—
Bouncing Bet (*Saponaria officinalis* L.)	—	—	
Bridalwreath (*Spiraea* spp.)		—	—
Buckwheat (*Fagopyrum esculentum* Moench.)	—		
Burdock (*Arctium minus* L.)	—	—	
Buttonbush (*Cephalanthus occidentalis* L.)	—		
Cabbage (*Brassica oleracea* L.)			—
Carrot (*Daucus carota* L.)		—	
Catalpa (*Catalpa speciosa* Warder)		—	
Cauliflower (*Brassica oleracea* L.)		—	
Cedar, Red (*Juniperus virginiana* L.)			—
Cedar, White (*Thuja occidentalis* L.)			—

Sulphur dioxide (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Grass Foxtail (*Setaria viridis* (L.) Beauv.)			—
Grass, Merion Blue (*Poa pratensis* L.)			—
Grass, Orchard (*Dactylis glomerata* L.)		—	—
Ground Ivy (*Glechoma hederacea* L.)	—		
Hazel, Beaked (*Corylus cornuta* Marsh.)		—	—
Hemlock, Eastern (*Tsuga canadensis* (L.) Carr.)	—	—	
Hollyhock (*Althaea rosea* Cav.)		—	
Honeysuckle (*Lonicera* spp.)			—
Hydrangea (*Hydrangea* spp.)		—	—
Iris (*Iris* spp.)		—	—
Jerusalem Cherry (*Solanum Pseudo-Capsicum* L.)			—
Lady's-Thumb (*Polygonum* spp.)	—		
Lamb's-Quarters (*Chenopodium album* L.)		—	
Larch, Eastern (*Larix laricina* (Du Roi) Koch)	—		
Lettuce* (*Lactuca sativa* L.)		—	
Lilac (*Syringa vulgaris* L.)			—
Linden, Little-leaf (*Tilia cordata* Mill.)		—	—

Sulphur Dioxide (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Celery (*Apium graveolens* L.)		—	—
Cherry, Choke (*Prunus virginiana* L.)		—	—
Cherry, Sweet (*Prunus avium* L.)		—	—
Chickory (*Cichorium Intybus* L.)	—		
Chickweed (*Stellaria media* (L.) Cyrillo)	—		
Chrysanthemum (*Chrysanthemum* spp.)		—	—
Clover, Red (*Trifolium pratense* L.)	—		
Clover, White (*Trifolium repens* L.)	—		
Clover, Yellow Sweet (*Melilotus officinalis* Lam.)	—	—	
Corn, Sweet (*Zea Mays* L.)			—
Cottonwood, Eastern (*Populus deltoides* Marsh.)		—	
Crabgrass (*Digitaria sanguinalis* Scop.)			—
Cucumber* (*Cucumis sativus* L.)		—	—
Cyprus Spurge (*Euphorbia Cyparissias* L.)			—
Daisy, Ox-eye (*Chrysanthemum Leucanthemum* L.)		—	

Sulphur dioxide (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Dandelion (*Taraxacum officinale* Weber)	—	—	
Dogwood, Red Osier (*Cornus stolonifera* Michx.)		—	—
Elderberry (*Sambucus pubens* Michx.)			—
Elm, American (*Ulmus americana* L.)		—	
Elm, Chinese (*Ulmus parvifolia* Jacq.)	—		
Fern, Bracken (*Pteridium aquilinum* (L.) Kuhn)	—		
Fir, Balsam (*Abies balsamea* (L.) Mill.)		—	
Fir, Douglas* (*Pseudotsuga menziesii* Franco)	—	—	
Forsythia (*Forsythia viridissima* Lindl.)		—	—
Galinsoga (*Galinsoga ciliata* (Raf.) Blake)	—	—	
Geranium* (*Pelargonium* spp.)	—	—	
Ginkgo (*Ginkgo biloba* L.)			—
Gladiolus (*Gladiolus* spp.)		—	—
Grape, Wild (*Vitis labrusca* L.)		—	—
Grass, Annual Blue (*Poa annua* L.)		—	—
Grass, Barnyard (*Echinochloa crusgalli* L.)			—

Sulphur dioxide (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Maple, Manitoba (*Acer Negundo* L.)			
Maple, Mountain (*Acer spicatum* Lam.)			
Maple, Norway (*Acer platanoides* L.)			
Maple, Silver (*Acer saccharinum* L.)			
Maple, Sugar (*Acer saccharum* Marsh.)			
Marigold (*Tagetes erecta* L.)			
Mayweed (*Matricaria maritima* L.)			
Milkweed, common* (*Ascelepias syriaca* L.)			
Mock Orange (*Philadelphus coronarius* L.)			
Moth Mullein (*Verbascum Thapsus* L.)			
Mountain Ash, European (*Pyrus Aucuparia* (L.) Gaertn.)			
Mustard, Black (*Brassica nigra* L.)			
Nightshade (*Solanum nigrum* L.)			
Oak, Pin (*Quercus palustris* Muenchh.)			
Oak, White *Quercus alba* L.)			
Oats (*Avena sativa* L.)			

Sulphur dioxide (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Onion, Garden (<u>Allium</u> <u>Cepa</u> L.)		—	—
Oxalis (<u>Oxalis</u> <u>stricta</u> L.)	—		
Pea, Garden (<u>Pisum</u> <u>sativum</u> L.)		—	
Peach (<u>Prunus</u> <u>Persica</u> (L.) Batsch.)		—	—
Pigweed (<u>Amaranthus</u> <u>retroflexus</u> L.)	—	—	
Pine, Austrian (<u>Pinus</u> <u>nigra</u> Arnold)		—	
Pine, Eastern White* (<u>Pinus</u> <u>Strobus</u> L.)	—	—	
Pine, Jack (<u>Pinus</u> <u>banksiana Lamb.)</u>	—		
Pine, Red (<u>Pinus</u> <u>resinosa</u> Ait.)		—	
Pine, Scotch (<u>Pinus</u> <u>sylvestris</u> L.)	—		
Plantain (<u>Plantago</u> <u>major</u> L.)	—		
Plum (<u>Prunus</u> <u>domestica</u> L.)		—	—
Poplar, Balsam (<u>Populus</u> <u>balsamifera</u> L.)		—	—
Poplar, Lombardy (<u>Populus</u> <u>nigra</u> var. <u>italica</u> Du Roi)	—		
Potato, White (<u>Solanum</u> <u>tuberosum</u> L.)			—

Sulphur dioxide (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Privet (*Ligustrum* spp.)			———
Prune, Italian (*Prunus domestica* L.)		———	
Pumpkin (*Cucurbita Pepo* L.)	———		
Purslane (*Portulaca oleracea* L.)			———
Radish (*Raphanus sativus* L.)	———	—	
Ragweed (*Ambrosia artemisiifolia* L.)	———		
Raspberry, Red (*Rubus idaeus* L.)		———	—
Rhubarb (*Rheum Rhabarbarum* L.)	———		
Rose, Tea* (*Rosa odorata* Sweet.)		———	———
Rye (*Secale cereale* L.)	———		
St. John's-Wort (*Hypericum* spp.)	———	—	
Soybean (*Glycine Max* (L.) Merr.)	———		
Spinach (*Spinacia oleracea* L.)	———		
Spruce, Colorado Blue* (*Picea pungens* Engelm.)	———	—	
Spruce, Norway (*Picea Abies* (L.) Karst.)	———	—	

Sulphur dioxide (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Spruce, White (*Picea glauca* (Moench) Voss)			—
Strawberry (*Fragaria* spp.)		—	
Sunflower (*Helianthus annuus* L.)	—		
Swiss Chard (*Beta vulgaris* var. *Cicla* L.)	—		
Tobacco (*Nicotiana Tabacum* L.)	—		
Tomato (*Lycopersicon esculentum* Mill.)		—	
Tulip (*Tulipa Gesneriana* L.)			—
Violet (*Viola* spp.)	—		
Virginia Creeper (*Parthenocissus quinquefolia* Planch.)			—
Wheat (*Triticum aestivum* L.)	—		
Yarrow (*Achillea Millefolium* L.)	—		
Yew (*Taxus* spp.)		—	
Zinnia (*Zinnia elegans* Jacq.)	—		

* These species vary widely in their response to sulphur dioxide; some individuals or populations may be susceptible, others very resistant.

AMMONIA

Susceptibilities of Selected Plants to Ammonia

Plant Species	Susceptible	Intermediate	Resistant
A. Trees and shrubs			
Apple (*Malus sylvestris* Mill.)		—	
Apple, flowering crab (*Malus sieboldii* (Regel) Rehd.)		—	
Aspen, trembling (*Populus tremuloides* Michx.)	—	—	
Ash, white (*Fraxinus americana* L.)	—	—	
Birch, white (*Betula papyrifera* Marsh.)	—	—	
Box-elder (*Acer negundo* L.)			—
Butternut (*Juglans cinerea* L.)	—		
Catalpa (*Catalpa bignonioides* Walt.)	—	—	
Cherry, choke (*Prunus virginiana* L.)			—
Cherry, sour (*Prunus cerasus* L.)		—	
Clematis (*Clematis jackmanii* Moore)		—	
Dogwood (*Cornus racemosa* Lam.)		—	
Dogwood, flowering (*Cornus florida* L.)		—	
Dogwood, red osier (*Cornus stolonifera* Michx.)		—	—
Elm, American (*Ulmus americana* L.)		—	
Forsythia (*Forsythia viridissima* Lindl.)		—	—

Ammonia (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Hawthorn (*Crataegus* spp.)	—		
Hornbeam, hop (*Ostrya virginiana* (Mill) K. Koch.)	—		
Ivy, English (*Hedera helix* L.)			—
Juniper, spreading (*Juniperus chinensis* L.)			—
Lilac (*Syringa vulgaris* L.)		—	
Linden (*Tilia americana* L.)		—	
Maple, Norway (*Acer platanoides* L.)			—
Maple, silver (*Acer saccharinum* L.)			—
Maple, silver (seedlings)	—	—	
Maple, sugar (*Acer saccharum* Marsh.)			—
Mock-orange (*Philadelphus coronarius* L.)	—		
Mulberry, red (*Morus rubra* L.)	—		
Oak, red (*Quercus rubra* L.)		—	
Oak, swamp white (*Quercus bicolor* Willd.)		—	
Peach (*Prunus persica* (L.) Batsch.)		—	—
Pine, mugo (*Pinus mugo* Turra)			—
Pine, white (*Pinus strobus* L.)			—
Plum (*Prunus domestica* L.)		—	

Ammonia (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Poplar, balsam (*Populus balsamifera* L.)	—		
Privet (*Ligustrum ovalifolium* Hassk.)	—	—	
Raspberry, red (*Rubus idaeus* L.)	—		
Rose, hybrid tea (*Rosa odorata* Sweet)		—	
Snowberry (*Symphoriocarpos albus* L.)	—		
Spiraea (*Spiraea vanhouttei* Zabel)	—	—	
Spruce, Norway (*Picea abies* Karst)			—
Spruce, white (*Picea glauca* (Moench) Voss)		—	—
Sumac, staghorn (*Rhus typhina* L.)		—	—
White cedar, northern (*Thuja occidentalis* L.)			—
Yew, Japanese (*Taxus cuspidata* Sieb. & Zucc.)			—
B. Cultivated plants			
Alfalfa (*Medicago sativa* L.)		—	
Asparagus (*Asparagus officinalis* L.)		—	
Barley (*Hordeum vulgare* L.)	—		
Bean, pole (*Phaseolus vulgaris* L.)	—		
Beans, scarlet runner Phaseolus coccineus L.	—		
Beet Beta vulgaris L.		—	—

Ammonia (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Rhubarb (*Rheum rhabarbar-um* L.)			—
Soybean (*Glycine max* Merr.)	—	—	
Strawberry (*Fragaria* spp.)		—	
Sunflower (*Helianthus annuus* L.)		—	
Tomato (*Lycopersicon esculentum* Mill.)		—	—
C. Other herbaceous plants			
Bladder campion (*Silene cucubalus* Wibel)	—		
Burdock (*Arctium minus* (Hill) Bernh.)	—		
Catnip (*Nepeta cataria* L.)	—		
Clover, red (*Trifolium Pratense* L.)	—	—	
Clover, white sweet (*Melilotus alba* L.)	—		
Cichory (*Cichorium intybus* L.)			—
Carrot, wild (*Daucus carota* L.)			—
Daisy, ox-eye (*Chrysanthemum leuc anthemum* L.)	—		
Dandelion (*Taraxacum officinale* Weber)		—	
Goldenrod (*Solidago canadensis* L.)		—	
Goldenrod (*Solidago nemoralis* Ait.)	—	—	

Ammonia (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Cabbage (*Brassica oleracea* var. *capitata* L.)		—	
Carrot (*Daucus carota* var. *sativa* DC.)		—	—
Corn (*Zea mays* L.)			—
Cucumber (*Cucumus sativus* L.)		—	—
Dahlia (*Dahlia pinnata* Cav.)		—	
Eggplant (*Solanum melongena* L.)		—	—
Grass, K. blue (*Poa pratensis* L.)			—
Grass, Timothy (*Phleum pratense* L.)	—	—	
Hollyhock (*Althaea rosea* Cav.)	—	—	
Marigold, French (*Tagetes patula* L.)		—	
Onion (*Allium cepa* L.)			—
Peas, garden (*Pisum sativum* L.)	—		
Pea, sweet (*Lathyrus odoratus* L.)	—		
Peony (*Paeonia suffruticosa*)	—	—	
Petunia (*Petunia hybrida* Vilm.)		—	
Phlox (*Phlox paniculata* L.)		—	
Potato (*Solanum tuberosum* L.)		—	—
Radish (*Raphanus sativus* L.)	—		

Ammonia (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Grass, quack (*Agropyron repens* (L) Beauv.)		—	—
Grass, smooth brome (*Bromus inermis* Leyss)		—	—
Ground ivy (*Glechoma hederacea* L.)		—	
Knotweed, Japanese (*Polygonum cuspidatum* Sieb. & Zucc.)		—	
Lambs-quarters (*Chenopodium album* L.)	—		
Lettuce, prickly (*Lactuca scariola* L.)	—		
Milkweed (*Ascelepias syriaca* L.)		—	—
Motherwort (*Leonurus cardiaca* L.)	—	—	
Mustard, black (*Brassica nigra* (L) Koch.)	—	—	
Nightshade, climbing (*Solanum dulcamara* L.)		—	
Pigweed (*Amaranthus hybridus* L.)			—
Ragweed (*Ambrosia artemisiifolia* L.)	—		
Sorrel, sheep (*Rumex acetosella* L.)		—	
Smartweed (*Polygonum persicaria* L.)	—	—	
St. Johns'-wort (*Hypericum perforatum* L.)			—
Teasel (*Dipsacus sylvestris* Huds.)	—		

Ammonia (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Thistle, Canada (*Cirsium arvense* L.)			
Thistle, sow (*Sonchus arvensis* L.)			
Thistle, sow (*Sonchus asper* L.)			

HYDROGEN CHLORIDE

Susceptibilities of Selected Plants to Hydrogen Chloride

Plant Species	Susceptible	Intermediate	Resistant
Ageratum (*Ageratum* spp.)		—	
Ash, red (*Fraxinus pennysylvanica*)	—		
Basswood (*Tilia americana*)	—		
Bean, faba (*Vicia faba*)	—		
Bean, scarlet runner (*Phaseolus coccineus*)	—		
Blackberry (*Rubus occidentalis*)		—	
Birch, white (*Betula papyrifera*)		—	
Cabbage (*Brassica oleracea* cv. *capitata*)			—
Chard, Swiss (*Beta vulgaris* cv. *cicla*)		—	—
Clover, white (*Trifolium repens*)			—
Cottonwood, eastern (*Populus deltoides*)			—
Dogwood (*Cornus* spp.)	—	—	
Elm, american (*Ulmus americana*)	—	—	
Fern, bracken (*Pteridium aquilinum*)	—	—	
Gladiolus (*Gladiolus* sp. cv. *Snow Princess*)		—	—
Goldenrod (*Solidago* spp.)		—	
Grape, wild (*Vitis riparia*)			—
Hawthorn (*Crataegus* spp.)	—		
Hickory, shagbark (*Carya ovata*)		—	—
Maple, Manitoba (*Acer negundo*)		—	
Maple, silver (*Acer saccharinum*)	—	—	

Hydrogen Chloride (cont'd)

Plant Species	Susceptible	Intermediate	Resistant
Marigold (*Tagetes erecta*)		—	
Milkweed, common (*Ascepias syriaca*)		—	
Nightshade, common (*Solanum nigrum*)			—
Oak, bur (*Quercus macrocarpa*)	—		
Pepper, green (*Capsicum frutescens*)		—	—
Pine, Scots (*Pinus sylvestris*)		—	—
Pine, white (*Pinus strobus*)	—	—	
Potato (*Solanum tuberosum*)	—	—	
Ragweed, common (*Ambrosia artemisiifolia*)		—	
Raspberry, red (*Rubus idaeus*)		—	—
Salix (*Salix* spp.)		—	
Salvia (*Salvia* spp.)	—	—	
Soybean (*Glycine max*)	—		
Sumac, staghorn (*Rhus typhina*)	—		
Teasel (*Dipsacus sylvestris*)	—	—	
Tomato (*Lycopersicon esculentum*)	—	—	
Trefoil, tick (*Desmodium* spp.)			—
Turnip (*Brassica rapa*)			—
Yarrow (*Achillea* spp.)		—	—

CHLORINE

Susceptibilities* of Selected** Plants to Chlorine

Susceptible

Crabapple
Eastern white pine
Peony
Pear
Delphinium
Privet

Weigela
Boston ivy
London Planetree
Magnolia
Goutweed

Intermediate

Lilac
Brown-eyed Susan
Geranium
Scarlet Trumpet Honeysuckle
Barberry
Elderberry
Lily-of-the-Valley
Hosta Lily (H. plantaginea)
Staghorn Sumac
Juniper
Locust
Bush bean
Cinquefoil
Egg plant
Carrot
Tomato
Zinnia

Norway Maple
Manitoba Maple (Box elder)
Common Plantain
Forsythia
Wysteria
Rhubarb
Salvia
Dusty miller

Brussel Sprouts
Chinese elm
Mugho pine
Austrian pine
Tomato
Viburnum
Cabbage
Cucumber
Yellow Wax Bean

Resistant

Silver maple
Rose-of-Sharon
Yew
Petunia
Russian olive
Pepper (green)
Eastern White Cedar
White birch
Iris
Impatiens

* species are not placed in order of sensitivity within groups, but plants in left-hand columns were more sensitive than those in right-hand columns of each group.

** based on a single incident in Sarnia, 1980

CHAPTER 5: INVESTIGATION PROCEDURES

A External Requests

The complainant or designated spokesman requesting an investigation into an alleged adverse effect caused by environmental contamination should report the details of the incident either to a Regional Office or directly to the Phytotoxicology Section, Air Resources Branch. The details of the complaint are entered on a PS1 form (attached) and the investigation is assigned to the appropriate field staff and a tentative investigation date established. The Regional Abatement and Technical Support Managers are subsequently notified of the complaint (speedy memo with PSI) and of the tentative investigation date. Arrangements should be made by the investigator-in-charge to visit the complainant's premises, and, if expedient, to have specialists from other government departments join the investigative party. At this time, if the investigator-in-charge is confident that the problem is related to source emissions the complainant must be advised that in order to gain access to the services of the Board of Negotiation in any subsequent financial settlement the alleged source of contamination must be notified in order that they may examine the injury and take samples for their own laboratory examination.

In order to ensure that both parties are given the proper notice a speedy memo form (Vegetation/Livestock Complaint Investigation Notice) has been prepared (attached). The new procedure which should be followed by the investigator-in-charge in all cases where it appears that the complaint investigation will implicate an offending source is as follows:

1. fill in the complainant's name and address;
2. have the complainant sign the form either granting or denying the alleged source permission to come on property to view the injury or to take samples;
3. fill in the alleged source's name and address;
4. sign and date the form;
5. give the complainant the YELLOW copy;
6. if the complainant signs PERMISSION GRANTED, visit the alleged source and give the representative the PINK copy (if unoccupied forward PINK copy by registered mail); return the original (WHITE) copy to the main file

at 880 Bay Street;

7. if the complainant signs PERMISSION DENIED, return the original (WHITE) copy and the PINK copy to the main file at 880 Bay Street.

Although it is not possible to follow a specific set of investigative procedures in every case, the following general guidelines should be reviewed after each investigation to ensure that nothing has been missed.

1. Determination of timing of injury development and relationship to weather conditions
2. Determination of cultural practices used by the owner
3. Presence of insect and disease manifestations
4. Observations on degree of visible injury - percentage of leaf and plant affected for each species - and on the pattern of injury development
5. Presence of injury on other plant species with description of symptoms
6. Sketch of the complainant's property showing location of injured and non-injured vegetation
7. Drawing of the pattern of injury between the complainant's property and the indicated source of air pollution
8. Photographs (35 mm. color) of the injuries or other pertinent factors
9. Collection of samples from the complainant's property for laboratory purposes (chemical, herbarium, pathology, histology, other)
10. Collection of samples from at least one control area located at a safe distance from the indicated source i.e. soil, from the same depths and vegetation from the same plant species and varieties as those injured at the complainant's property should be sampled.

B Assessment Surveys

Following the receipt of a request for an assessment survey investigation, a PS1 form is completed and an investigator assigned. The region from which the request originated is notified of the approximate timing of the survey and the investigator-in-charge begins by considering a number of pertinent details:

What environmental contaminants are to be considered in the survey?

The information on the nature of the contamination is usually provided by the originating Regional Technical Support or Industrial Abatement Officer when a request for a survey is made. If a clarification or extension to this request is considered advisable by the investigator-in-charge, the originating officer should be contacted.

How widespread is the problem?

Generally the originating official can provide a rough estimate of the geographical extent of the problem from known or calculated emission rates and dispersions, and can compare the newly requested source to similar sources that have been previously surveyed. Such information is not essential but permits the investigator to estimate the size of his assessment survey network.

1 Survey Type or Emphasis

The form of the assessment survey will depend on the type of contaminant being emitted by the source. Essentially, most surveys will have two major components: 1) an inspection of vegetation for injury and 2) a sampling of vegetation (usually foliage) for accumulation of contamination. The following table summarizes the importance that should be placed on each of the two components for several different contaminants.

Assessment Survey Emphasis For Various Air Pollutants

Pollutant	Assessment Emphasis	
Ammonia	injury inspection only	
Arsenic	injury inspection + vegetation sampling	
Boron	injury inspection + vegetation and soil sampling (plant available)	
Chlorine	heavy emphasis on injury inspection; less emphasis on vegetation sampling	
Chloride	injury inspection + vegetation and/or soil sampling	
Fluoride	injury inspection and vegetation sampling	
Heavy metals	heavy emphasis on vegetation and/or soil sampling; less emphasis on injury inspection-some injury could be expected under very heavy contamination situations with certain metals.	
Hydrogen chloride	acute:	heavy emphasis on injury inspection; less emphasis on vegetation sampling
	chronic:	per chloride
Hydrogen fluoride	acute:	heavy emphasis on injury inspection; less emphasis on vegetation sampling
	chronic:	per fluoride
Mercury	heavy emphasis on vegetation and soil sampling; less emphasis on injury inspection	
Ozone	injury inspection with histology backup	
Sodium chloride	per chloride	
Sulphur dioxide	heavy emphasis on injury inspection; moderate emphasis on vegetation sampling where chronic sources are concerned	

2 Survey Configuration or Layout

Three general types of assessment survey layouts are routinely used: the radii system, the quadrant system and the grid system. Each of

these layouts can be modified in turn to suit the particular needs of the investigator. Figure 3 outlines each general type and one of the possible modifications of each. The advantages and disadvantages of each general type of survey are listed below.

Comparison of Different Sample Collection Configurations

Sample Collection System	Advantages	Disadvantages
Radii	can be quickly set up and suits areas where roads run at right angles; good for untracked forest areas or where large distances must be covered	large areas between the arms of the radii can be missed as distance from the source increases
Quadrant	combines the quick nature of the radius system with the coverage provided by the grid system	not as suitable where trends along a particular line from the source are to be determined
Grid	can provide a very comprehensive picture suitable for symapping; the risks of missing high contamination areas are minimized	costly to execute since stations usually number in excess of 25; often difficult to carry out due to lack of suitable sampling points

3 Species Selection and Survey Timing

Wherever possible, the same plant species should be sampled at each site in the survey in order that data comparisons can be made between stations. In southern Ontario it has been commonplace to

use silver, Manitoba or Norway maples with the result that a large data base has been established. If it is not possible to collect a single common species two species may be selected such that at any given station either one or the other, but preferably both, would be collected. Where even this degree of uniformity is difficult or impossible, complementary support studies such as moss bags or indicator plots should be considered.

There are instances where apparent "accumulator" species should be avoided. These include:

zinc and cadmium:	Salix sp., Populus sp. and white birch
sulphur:	tomato and numerous grasses
boron:	Manitoba maple
fluoride:	hickory, American elm, spinach

Assessment surveys for vegetation contamination (metals and other non-gaseous contaminants) are commonly carried out in August or September. Earlier surveys may miss significant contamination buildup; later surveys may be compromised by an early leaf fall.

Since even year to year changes in soil concentrations are usually very small for most contaminants and sources, soil surveys can be carried out at any time when the soil is not frozen. Usually, however, soil and vegetation samples are collected at the same time to reduce travelling time and cost. In the case of gaseous or phytotoxic contaminants, the survey should be designed to ensure visual inspection and/or sample collection during the early, mid and late season periods.

4 Control Site Selection

Controls for assessment surveys should be chosen from locations that best replicate the environmental conditions in the vicinity of the source but are out of the zone of environmental influence of the source. This may be difficult around new sources where the extent of contamination is not known; however, adjustments of control zones in follow-up surveys is acceptable. Controls should be collected for all

plant species and soils collected in the survey zone and should be subject to the same sampling method guidelines as samples from the main body of the survey. Controls should be selected from areas with similar vehicular, residential and industrial activity as the source area.

5 Participation by Industry Personnel

Company personnel do not usually accompany Phytotoxicology personnel on assessment surveys but should be offered the opportunity to participate. Such participation can serve to increase the company's awareness of procedures for Phytotoxicology surveys and company personnel can use the opportunity to take duplicate samples for independent comparative analysis. Where parallel samples are taken, company personnel may participate in the sampling under supervision of the investigator-in-charge and utilizing the appropriate M.O.E. sampling techniques.

C Auxiliary Support Techniques

In certain instances, auxiliary support studies are carried out to augment the main assessment survey or complaint investigation. These complementary studies are usually initiated in cases where there is an inherent deficiency in the basic survey layout such as the lack of suitably sensitive plant species in the survey area or the lack of plant species suitable for chemical analysis sampling. Other types of auxiliary support are discussed separately in the following sections.

1 Indicator Plots

Living plants have been used for decades by numerous researchers and control agency personnel as indicators of the adverse effects of air pollution. Although "in situ" vegetation can be used, it is common place to set out specimens of specific clones which have known histories of high sensitivity to the one or more air pollutants.

The effect of this exercise is to extend the range of sensitivity of observable plant material at one or more chosen locations in a study area.

An outline of the classification of air pollution indicators is shown in Fig. 4. At the extreme left are those groups of plants referred to as indicators. These groups are simply native species or species introduced as crops or ornamentals which are already present in the area before commencement of the study. The principal advantage of using such plant groups is that the data extracted from the study area is wholly relevant to local growers or other concerned individuals. It may not, however, be possible to demonstrate a good correlation between the air quality data and plant response. Environmental conditions such as temperature, humidity and rainfall may alter greatly the susceptibility of these groups. Since these groups probably do not represent cloned material, plant to plant variability can be high. At the extreme right of Fig. 4 are groups of plants referred to as monitors. Their advantage is consistently good correlation between pollution concentration and injury development; their principal disadvantage is lower relevance with respect to locally grown crops or ornamentals.

a) Gladiolus

Sensitive varieties of gladiolus plants are used to indicate the presence of potentially phytotoxic air-borne fluoride around many types of industrial sources.
Fluoride injury to the terminal portions of the older leaves is characterized by tan-colored necrotic tipping with a narrow darker band separating the necrotic and healthy tissue. Plots in close proximity to a fluoride source usually develop a greater degree of foliar injury with the resulting necrotic lesions encompassing more of the terminal blade portion and spreading downwards along the leaf margins.

Although plot size and injury evaluation techniques have changed considerably in previous years, the current system adequately meets the following primary objectives of the program:

i) to provide visual confirmation of the presence of phytotoxic levels of air-borne fluoride, and

ii) to provide an ancillary data base which can be used to complement the chemical analyses results and to permit the comparison of the severity of fluoride emission effects from year to year.

One plot consists of 10 Snow Princess gladiolus corms planted in peat pots (4-5 litre). The pots are placed in a shallow trench which is dug slightly deeper than the height of the pots. One, 3 cu. ft. bag of horticultural vermiculite is emptied into the trench and the pots are worked in until their tops are level with the surface of the ground. The plot is watered with 25 litres of tap water and soil is raked over top until the pots are just covered. If the plot is located in a garden or field it may be necessary to stake the boundaries and tie flagging tape to the stakes.

The plants are harvested 14 weeks after the potted corms are set-out in the field. The tallest and shortest plants are discarded in the field. The corms should be removed immediately after harvesting and identified as to their location. The pots are left in the ground and should be completely decomposed by the next field season when, if desired, another plot can be established at the same location.

In the laboratory 4 plants are chosen at random from the 8 harvested at each station. The choice can be accomplished with either a random numbers table or simply from a"blind hat" draw. The leaves from the 4 plants from each plot are then utilized to determine the average leaf injury (on the basis of exposed leaf surfaces) per plot in the following manner: The youngest and oldest leaf from each plant is discarded and each of the remaining leaves(usually 3-5) are photocopied. The copier should be adjusted to light exposure so that the necrotic tissue is recognizable. After copying, the necrotic fluoride-injured areas should be highlighted in red on each sheet in order to avoid confusion with mimicking symptoms at a later date

when the copied material is measured. An identification template (shown below) also should be included with each leaf and will ensure that all of the pertinent information is recorded for each leaf sample.

The photocopying of all gladiolus leaves should be done as soon as possible after delivery to the processing laboratory.

Gladiolus Indicator Plant Template

Location ______________________________

Plot No. ______________________________

Plant No. ______________________________

Leaf No. ______________________________

Total Exposed Leaf Area ______________________

Total Injured Area ______________________

Calculated % Fluoride Injury ________________%

After photocopying, the measured leaves (exposed areas) from each plot are prepared for chemical analysis as unwashed samples. Depending on the size and number of leaves, two or three replications per plot are recommended. It is best not to rely on only one sample per plot as foliar fluoride concentrations can vary considerably.

Measurement of the leaves can be conducted with a standard planimeter or with an automated leaf area meter.

b) Tobacco

Because of its extreme sensitivity to atmospheric ozone, Bel-W3 tobacco has been extensively used as a bio-monitor of the potential for adverse vegetation effects on other ozone sensitive species. In Ontario, tobacco indicators have been employed to examine regional air mass contamination with ozone and to determine the influx associated with a large metropolitan complex. They also have been used to examine the ozone contribution from a large power plant source to the

already high ozone levels.

i) Planting

Because of the long lead time needed to produce healthy plant material, it is necessary to notify the Controlled Environment Unit of any tobacco requirements well before the field season and certainly no later than January of the year in which the plants are required. Plants which have been raised in the clean air greenhouse for approximately 60 days, are set out directly in soil at each field site in individual ½ gallon peat pots which have been fertilized for the duration of the field term. The top edges of each pot are ripped down to below soil level at time of planting to prevent the peat acting as a wick, drawing moisture from the roots. Plants are watered as often as possible but no less frequently than once a week. Biweekly sprays of a common insecticide may be required if aphids or hornworms are a problem. The configuration of the plants at each site is at the discretion of the investigator but is often dictated by available space. However, in order to avoid crowding at maturity the pots should be placed in the soil with a recommended spacing of 1 meter. Home gardens can be useful if residents will co-operate by providing additional water; however all sites must receive the same additional attention if valid comparisons are to be made between sites. Between 10 and 15 plants should be set out at each field site. This represents a viable compromise between the ideal number (25-35) needed for statistically reproducible data suitable for correlation with air quality data (i.e. bio-monitors) and the number considered practical (i.e. bio-indicators) from a logistical standpoint (greenhouse capacity, field investigator's time). Two groups of 10-15 tobacco plants are recommended for each site: the first group is planted after the last reasonable chance of frost (first week of June); the second group 4 weeks later. The first group of

plants is evaluated for ozone injury from the end of the first week on a weekly basis until eight evaluations have been made. The second group is evaluated at the end of its fourth week and on a weekly basis until five evaluations have been made. This system consequently provides 12 continuous weeks of data, 10 of which usually are selected for reporting purposes. The first 2 weeks data from group 1 often are not reliable since the plants require that time to acclimatize to outdoor conditions.

ii) Injury evaluation

Each tobacco plant is evaluated, from the ground up, leaf by leaf. Each leaf is scored on a percent injury basis using, if necessary, a series of foliar injury keys available from the Controlled Environment Unit (Figure 5). Records are kept on a form (attached) which permits the investigator to determine by simple subtraction, the amount of <u>new</u> injury that has developed on each leaf since the previous evaluation. The results (% <u>new</u> injury) from the three leaves exhibiting the greatest amount of new injury on each plant are averaged for all plants at the same site (i.e. 30-45 results are averaged). This single figure is then considered to be representative of the site for the week. By plotting these weekly figures against observation date, a trace for the plot is obtained which can be compared to traces for other sites in the survey area or to air quality data for the site, if available. However, these comparisons will not be valid unless tobacco at all sites in a survey area is evaluated on the same day.

2 Moss Bag Ion Receptors

Networks of standardized <u>Sphagnum</u> moss bags have been used for several years to monitor atmospheric emissions from numerous sources. Successful results have been achieved with the following elements; Pb, Cd, Ni, Zn, Co, Cu, Sb, Hg, As, Na, Ca, Cl, B, Fe, F,

Al, Cr and S. It has been determined that B Cl and Na may be leached from moss bags by rainfall, therefore a shorter exposure period or a system of wet weather protection is suggested for these elements.

The moss is purchased from a local supplier who has promised consistency of origin, moss quality and a reliable inventory. Using plastic or latex gloves, the moss is hand cleaned, removing sticks, stems, dead leaves and other assorted field debris associated with commercially-packaged moss. The picked fibers of Sphagnum moss are placed in plastic sample bags which are then filled with distilled water and left to soak overnight. The following day, the moss is rinsed three more times with distilled water and spread on plastic drying racks for a minimum of 48 hours.

Several samples should be collected and analyzed from each moss bag wash to determine the contaminant levels inherent in the moss. Experience has shown these pre-exposure batch control samples to be very consistent for most elements; however, this does not reduce the need or importance of field exposed control samples for all moss bag surveys.

Polypropylene screening with a mesh size of 1.5 x 2.0 mm is cut, folded and machine sewn to the dimensions illustrated in the accompanying Figures 6 and 7. Sleeves are sewn on the short side of the rectangular shaped screen bag to accommodate the plastic field holder. The moss bag is completed with the insertion of 3.0 g $\pm$ 0.1 g of air dried moss into the screen pouch, spraying with distilled water to work the moss into the corners and sewing the bag closed. The pouch measures approximately 15.5 x 6.5 cm and provides approximately 100 cm^2 of moss surface area. The completed moss bag is left to air dry before being placed in plastic bags for refrigerated storage. The plastic bags should be labelled with the appropriate moss wash number so that future comparison can be made with the analytical control data.

The field exposed moss bags should be utilized in conjunction with the plastic moss bag holder and support tube (Figure 8). The tube can be permanently attached in areas where surveys are conducted over several seasons. Moss bags should be attached to the pole/tree/structure about 3 m from the ground, but in areas where there has been repeated vandalism, it may be advisable to place the bags even higher. Past experiments have shown that contaminant levels in moss can vary at the same site when the bags are oriented in different compass directions relative to the source; therefore, it is recommended that the flat surface of the moss bag be pointed directly at the point of emissions.

The usual exchange time is one month, considered to be 28 to 31 days duration. It is important to have at least one good control site so that local background levels can be recognized. Exposed moss bags are assigned field numbers and placed in individual paper enclosure bags which are stapled closed . On arrival in the Processing Laboratory, the paper bags require no processing and can be placed directly in the drying ovens. After drying, the polypropylene screen can be cut away prior to homogenizing the moss in a Wiley mill. One exception to the oven drying process is moss bags for Hg analysis. These must be air dryed.

3 Bioassay Growth Studies

Bioassay growth studies can be used in a support or complementary role for all types of field investigations. Basically, they are special studies which are designed to provide information pertaining to adverse vegetation effects which otherwise would not be generated through the use of normal field investigation procedures. Although the designs and methods employed in these studies are virtually infinite in scope and defy the preparation of rigid methodology procedures, there are, nevertheless, several key rationale, applicable to all types of terrestrial vegetation on which the majority of these studies have been based:

i) to determine the relevance of soil contamination

ii) to differentiate between air and soil-borne contamination

iii)to determine or estimate the longevity of soil contamination

iv) to differentiate between multiple air-borne contaminants or emission sources

v) to establish guidelines for the removal and replacement of contaminated soils

vi) to identify and quantify the adverse effects of contaminated water supplies.

In any study of this type there are always several basic design considerations which must be addressed prior to formulating the experimental plan.

Some of the key considerations have been listed below:

i) Should the study be conducted 'in situ' as opposed to the clean air greenhouse or garden location?

ii) What type of growth container will best suit the experimental objective? i.e. pots, flats, 'in situ' planting, petri dishes

iii) What type of plants should be used in the study? i.e. native or natural species vs. common greenhouse or indicator species

iv) What type of soil medium should be used?

v) What type of irrigation water supply should be used? i.e. local water supply vs. greenhouse or distilled water source

vi) What type of planting method will be most suitable? i.e. direct seeding vs. transplanting

vii) Should pest control practices be employed? i.e. spraying for insect and disease control vs. hand roguing

viii) What type of fertility regime (if any) should be maintained?

ix) Should the study focus on germination effects, growth/yield impediment, foliar injury potential or reproductive effects?

x) How long should the study run? i.e. short term vs. long term effects

xi) What type of environmental conditions should be monitored or maintained?

xii) What degree of accuracy or confidence is required in the interpretation of the data? i.e. how many replications required

xiii) What types of data will best convey or describe the results of the bioassay? i.e. measurements, pictures chemical, pathological or histological information

Regardless of the type of bioassay methodology employed, the information which is generated will not be scientifically credible unless all information pertaining to the design rationale, experimental technique, climatic and edaphic parameters and data generation and analysis system are described in detail so as to permit validation of the results at a later date. Staff from the Controlled Environment Unit have prepared two forms (attached) which should be completed by each investigator who would like to utilize the C.E. or greenhouse facilities. Following completion of these forms a meeting between the investigator-in-charge and C. E. unit staff will be arranged before any work on the experiment can begin.

4 Leaf Litter Bags

Environmental stresses may not be as readily apparent as widespread destruction of the dominant types of vegetation. It is possible that continued stresses (i.e. fallout of metals) would have a negative effect on the biological components of the environment. This negative effect could be rather subtle and take some time to become obvious. One possible method of monitoring the subtle effects is to investigate the process of elemental cycling in the environment. This

cycling process might involve contaminants (in the foliage) which, upon reaching the soil, could affect biological agents involved in these natural cycling processes. Monitoring changes in the populations of these agents or their collective rate of activity (rate of leaf litter decomposition) may be accomplished by placing fixed amounts of leaf litter in the areas to be investigated and periodically following the fate of the leaf litter. By comparing the rates of decomposition in the area being investigated with those of a control area, it may be possible to determine if (and how) the environment is being affected.

1. Samples of test foliage or leaf litter are brought to the laboratory and stored temporarily at $4^{\circ}C$.

2. Samples are dried if required at $105^{\circ}C$ for 48 hours. Since this may be detrimental to certain types of organisms in the samples, it may be preferable to air dry samples. Similarly, fresh samples may also be used. However, when either fresh samples or air dry samples are used, a subsample must be oven dried to determine the moisture content, for calculating the dry weight of material placed in the bags.

3. Litter bags are prepared from fibreglass screening with 1 mm square openings. This size of mesh retains smaller particles of decomposing foliage; however, it also excludes some of the larger soil arthropods. Mesh sizes must be chosen as a compromise between these two factors.

4. The screening material is cut into 23 X 30 cm rectangles. These are folded and the shorter sides are sewn together with invisible thread 3 cm from the edge to form a pouch.

5. Ten grams of dried leaf material are placed in each envelope which is then sewn closed.

6. Prepared litter bags should be numbered and weighed prior to placement in the field if the contents are to be weighed and extracted for arthropods, etc., after collection.

7. Prepared litter bags are placed in the field in a predetermined experimental plan. Bags should be placed on the ground at a

level comparable to the leaf litter represented by the material within the bag.

8. Litter bags are exposed for various periods according to the experimental plan.

9. Litter bags are collected, placed individually in plastic bags and transported in coolers to the laboratory.

10. Bags are weighed, extracted for arthropods, dried, processed for chemical analysis, etc., according to experimental plan.

5 Snow Sampling

a) Site Selection

A snow sampling survey should be designed to provide an adequate number of sample points to cover the area considered to lie within the zone of contamination. Two control samples, remote from any known source of pollution, are recommended for each investigation. Sample sites should be in undisturbed locations, away from roads or other local sources of contamination, sufficiently open to permit the free fall of snow, but not exposed to excessive drifting. It may also be desirable to establish collection sites near air quality monitors or precipitation samplers. A sketch map should be prepared for each site, with sufficient detail to enable the sample point to be relocated for future surveys.

b) Sample Collection

To avoid contamination from dead vegetation or other matter near the ground, snow sampling should preferably be undertaken only when total depth of snow cover exceeds 25 cm. For special studies, it may be desirable to undertake "event sampling", in which the complete profile of fresh snow from a single snowfall is collected. More commonly, the profile of the entire snow cover is sampled. In either case, the surface area sampled should be recorded. The quantity of snow required from each location will depend on the kinds of parameters for which analyses are required. Generally, sufficient snow to yield

2 litres of meltwater is ample. Samples are collected with a clean, plastic, hollow cylinder, open at both ends, and free of metallic parts. The cylinder should preferably be of sufficient length to accommodate the total depth of snow expected on the ground. Cylinder diameter of about 15 cm, or somewhat larger, has been found suitable, although other convenient sizes would be equally acceptable. For snow of modest depth (up to 30 cm), a standard dustfall jar with bottom removed is a suitable sampling device. The cylinder is inserted in the snow to ground level.

Snow is then manually cleared from around one side of the cylinder and the cylinder lifted about 5 to 10 cm off the ground. A clean, hard, plastic device (e.g. toy shovel, dustpan, piece of plexiglass) is inserted under the base of the cylinder and the cylinder raised from the ground. The collected snow is transferred to a clean, heavy-gauge polyethylene bag and retained in unmelted condition until ready for processing. The number of cores obtained from each site is recorded, as well as the total depth of snow, depth of fresh snow and the kind and amount of visible surface and subsurface contaminants. If available, meteorological records of recent snowfall (10-day period prior to sampling) may be useful in interpreting final results. To avoid loss of data and to assist in interpreting anomalous results, it is recommended that duplicate samples be collected at each site.

6 Etiolated Pea Seedlings

Certain varieties of peas (Pisum sativum L.) when grown in the dark are extremely sensitive to atmospheric ethylene at concentrations as low as 10 ppb. The growth effects include:

1. reduction in the longitudinal growth rate at low ethylene concentration for periods less than 12 hours of continuous exposure

2. thickening and geotropic bending at the growing point at higher ethylene concentrations and longer duration exposures

and 3. cessation of all growth at high ($>$ 750 ppb) ethylene concentrations.

In all cases, there is a direct relationship between the observed effects and the ethylene concentration making this a very useful biomonitor for adverse ethylene effects. Unlike other plant indicators, the growth of the etiolated peas returns to normal within 15 minutes of the removal of the ethylene.

The only limitation to the use of these plants as biomonitors is that temperature within the dark growth area must be regulated or monitored as it also has an effect on the growth of the plants. If it is known that there will be location differences in temperature a thermograph can be used and the effects of temperature can be estimated. This procedure will eventually be computer programmed.

The following is a recommended procedure for the use of etiolated peas. It was developed by staff from the Controlled Environment Unit, and any questions concerning its use should be directed to D. S. Harper or R. D. Jones.

1. Fill a half flat (31.3 x 22.9 x 6.7 cm I. D. cedar) with <u>fine</u> vermiculite, level to top and compress with sowing board (Fig. 9) to 1 cm below the top of the flat.

2. Place sowing board with 35 uniformly spaced holes (Fig. 9) on top of vermiculite and place one seed (Pisum satium L. cv. Alaska) in each hole. Using a plunger (Fig. 9) push seed into vermiculite to 1.5 cm depth.

3. Bottom soak the flat in room temperature water until thoroughly wet, then drain off excess water.

4. Place a moisture retention cover (Fig. 9) over the vermiculite

5. Place flat in completely dark location at 25°C (note: do not put in ethylene scrubbed system when germinating) preferably a growth chamber.

6. a) When using the peas for a one week exposure period, sow 144 hours before placing them in the field. The peas should be 6-8 cm tall.

   b) When using the peas for a period of two to four days of exposure sow them 168 hours before placing in the field. The peas should be 10-12 cm tall.

   Note: exposure periods in excess of one week are not advisable.

7. Before transporting to the field, bottom soak the flat until thoroughly saturated and drain off excess water.

8. The flat should be transported to the exposure location in a light-tight box. The transfer box (Fig. 10) should have an ethylene scrubbing system of potassium permanganate impregnated vermiculite or Purafil to remove ethylene if the peas are to be in the box for longer than eight hours.

9. The height of all the peas should be measured just before the flat is put in the exposure box and the time of measurement recorded.

10. Place flat in exposure box. There are at present three types of exposure boxes. The first box is a passive flow design that can be placed anywhere with no support facilities need. The major disadvantage of the passive design is poor air flow (Fig. 11). The other two boxes have forced air ventilation and may be heated. These boxes have better ventilation and fewer light leaks. They do, however, require a power outlet. These two

boxes are basically the same. One has only one compartment for exposing a flat (Fig. 12). The other box has two compartments, one compartment receives ambient air, the other receives ethylene scrubbed air (Fig. 13) and is used as a control.

Care should be taken when locating exposure boxes with respect to temperature at each location and exposure to the sun.

11. At the end of the exposure period the flat is removed from the exposure box and the pea heights measured immediately. Record the time of measurement. The height is measured from the top of the moisture retention cover. The height of each node may also be measured. If the ethylene concentrations are high enough to cause thickening and geotropism, the height at which this occurs should be measured. Also measure the angle of the bend. Pictures should also be taken.

12. The initial height for each plant is subtracted from the final height. The average increase in height is then calculated. Because the initial height is substracted from the final height it is important that the heights are measured and recorded in the same order. The average internode lengths may also be calculated if they were measured. The average heights at each location are compared against the control and a percentage difference determined.

    Due to the large variability between plants, a 5% difference with respect to the control is visually not significant. Statistical "t" tests can be preformed to determine significance. When the difference is 20% or greater there is a possibility of ethylene injury to sensitive plants.

Ministry of the Environment
Ontario

External Request________

Assessment Survey______

PHYTOTOXICOLOGY SECTION

AIR RESOURCES BRANCH

REQUEST FOR SOIL AND VEGETATION ASSESSMENT INVESTIGATION

Date Received________________19_____Telephone_________Letter________

Other____

Requested by:____

Address____Phone:_____________

Region____

Alleged Source of Air Pollution_____________________________________

Source Address____

____

Nature of Request____

____

____

____

____

____

Received by:____

Tentative Investigation Date and Investigator(s)____________________

____

Remarks (Referred by)____

____

Form PS1

MOE 0148 3/79

(RETAIN THIS COPY FOR FOLLOW-UP)

7540-102

SEND TO

Complainant Name:

Address:

FROM

Phytotoxicology Section, Ministry of the Environment, 880 Bay Street, Ste. 347, Toronto, M5S 1Z8

SUBJECT

VEGETATION/LIVESTOCK COMPLAINT INVESTIGATION NOTICE

The Environmental Protection Act, specifies that in the case of complaints concerning injury or damage to vegetation or livestock suspected of being caused by an environmental contaminant the owner or person responsible for the alleged source of the contaminant shall be permitted access to the complainant's property to view the damage and take samples. Failure on your part to comply with this requirement could jeopardize any subsequent access to the Board of Negotiation in the event that a monetary claim is made following the investigation.

By copy of this notice we will, with your permission inform the owner or person responsible for the alleged source of your complaint, and of our investigation on this date. If this investigation confirms that the injury or damage on your property was caused by a contaminant(s) and identifies the source, both parties will receive a copy of the final investigation report and procedural details concerning access to the services of the Board of Negotiation.

REPLY

NOTIFICATION OF ALLEGED SOURCE

Permission granted ____________________ (Sign)

Permission Denied ____________________ (Sign)

cc: To: Alleged Source ____________________ Address ____________________

This notice which has been signed by a complainant alleges that a contaminant originating from your property was responsible for injury or damage on the complainant's property. According to the Environmental Protection Act, you have the right to view the damage and take samples.

REPLY FROM

MOE Investigator-in-Charge

REPLY DATE

Investigation Date

Ontario

RP/as: PH 1-22

TO WRITE: HANDWRITE OR TYPE REMOVE AND RETAIN YELLOW COPY FORWARD BALANCE OF SET

TO REPLY: WRITE REPLY IN BOTTOM AREA SNAP SET APART

FOLD AT MARKS FOR USE IN # 9 OR # 10 WINDOW ENVELOPE

RETAIN ORIGINAL AND RETURN PINK COPY

Figure 3: Assessment Survey Configurations

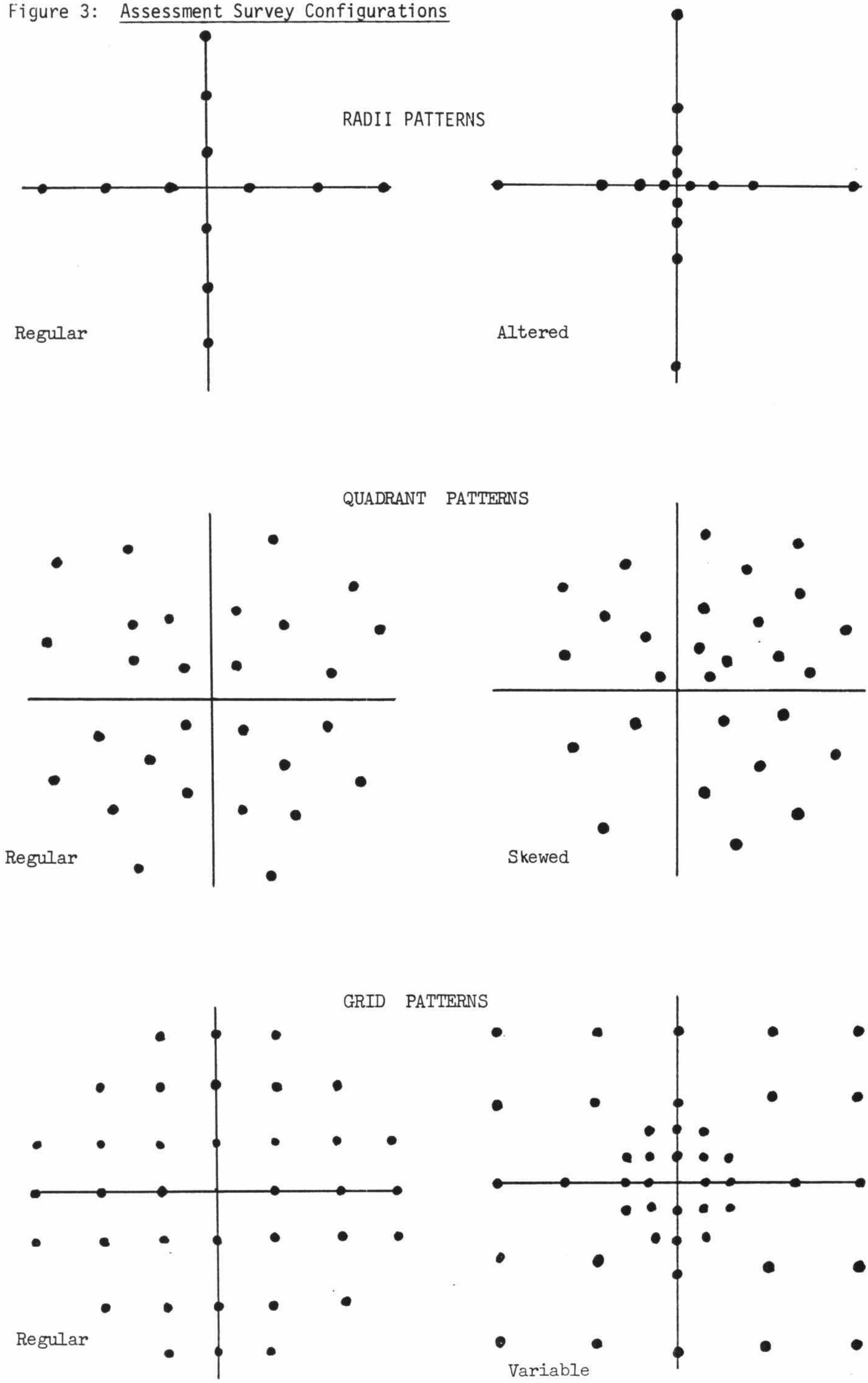


Figure 4: **Relationship Between Plant Indicators And Monitors For Air Pollutant Effects On Vegetation**

INDICATOR			MONITOR
Observe Sensitive Native Vegetation, Crops or Ornamentals	Establish Sensitive Native Species, Crops or Ornamentals (Direct Planting of Seed or Seedlings) Occasional Maintenance	Establish Sensitive Native, Economic or Non-Economic Species (Special Potting and Regular Maintenance)	Establish Native Economic or Non-Economic Species (Highly Modified Growing Conditions)

→ USUAL INCREASING CORRELATION BETWEEN A.Q. DATA AND PLANT RESPONSE

← USUAL INCREASING RELEVANCE TO LOCALLY GROWN CROPS OR ORNAMENTALS

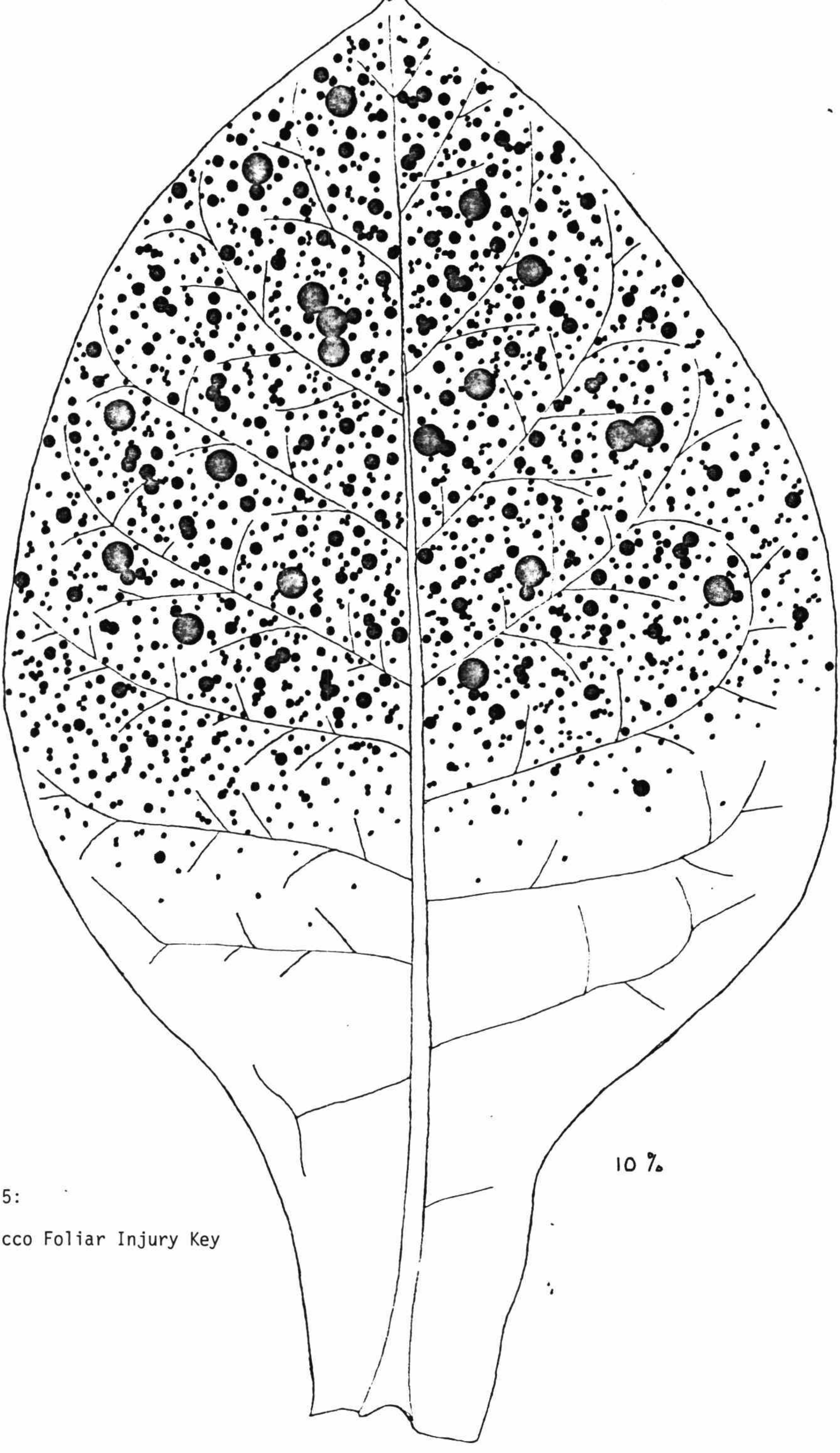


Figure 5:

Tobacco Foliar Injury Key

TOBACCO INJURY RECORD FORM

Study/Area ______________________ Plot No./Location ______________

Plant No. ______________________ Date Planted ______________ 198___

Leaf No.	Weekly Injury Evaluation (Enter Date Below)								
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									
33									
34									
35									
36									
37									
38									
39									
40									

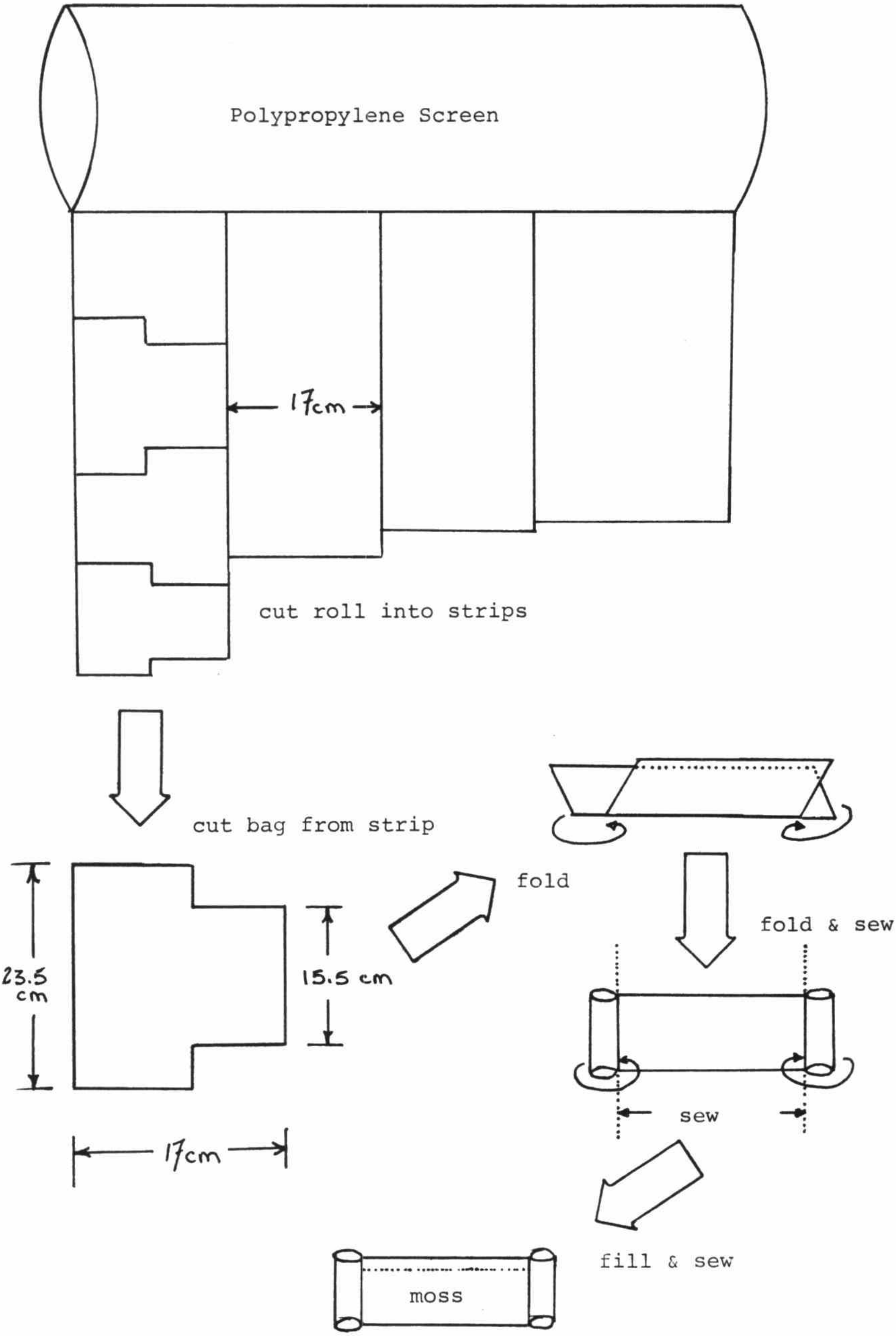
Code Descriptions:

V = No injury
T = Trace (< 1%)
D = Disregard (> 60% injury)
B = Leaf broken
15 = Circled number is leaf with a tag (reference leaf)

Suggested % Injury Values

V T 1 3 5 7 10 15 20 25 30 40 50 60 D

Figure 6: Moss Bag Screen Preparation



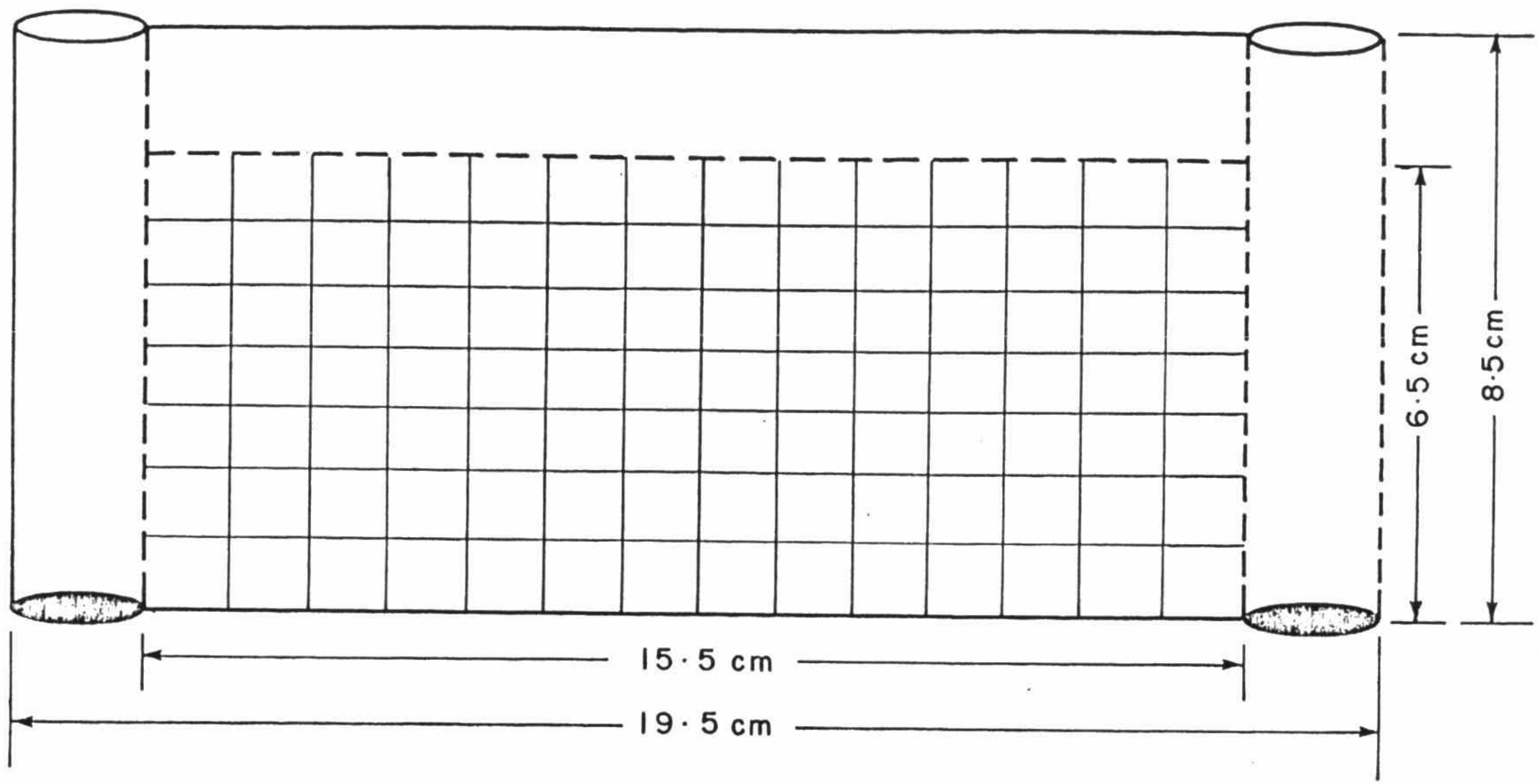
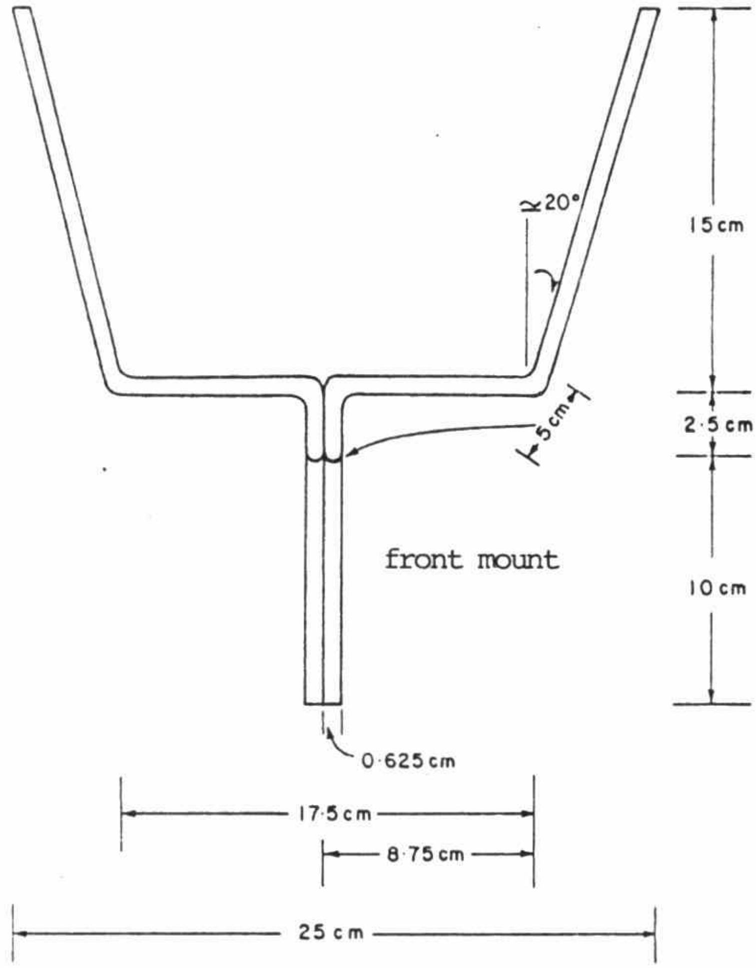
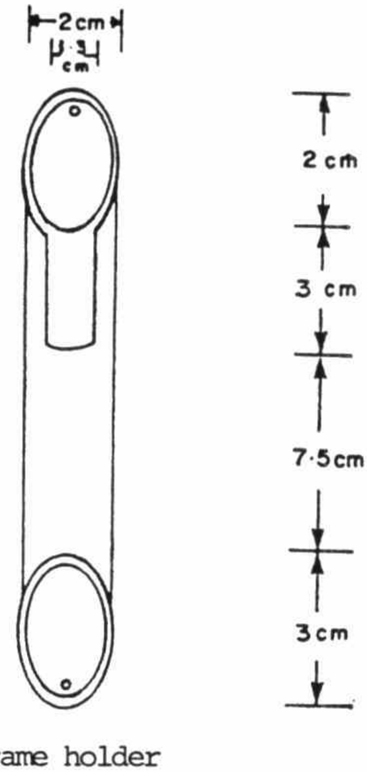
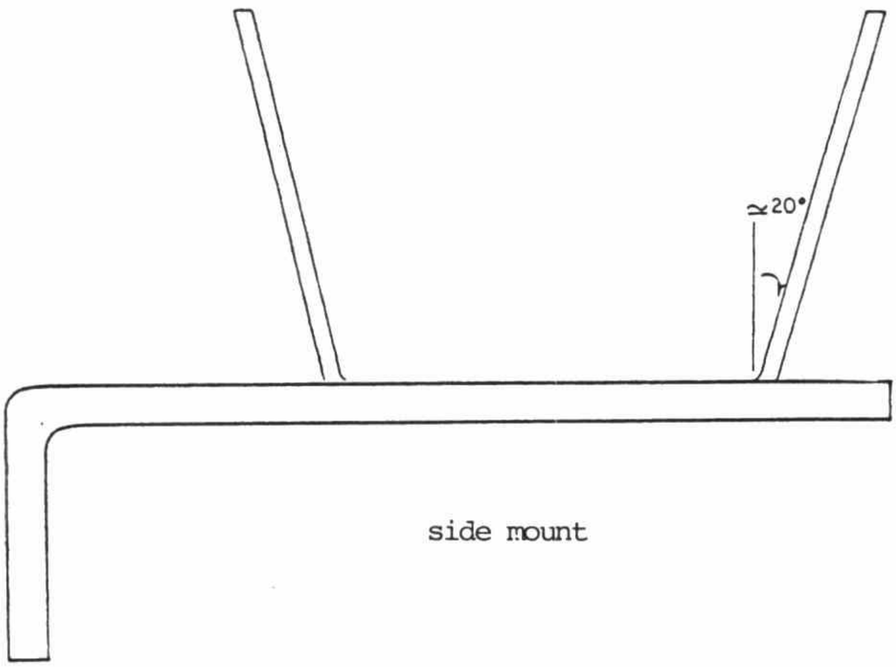


FIGURE 7: Completed Moss Bag







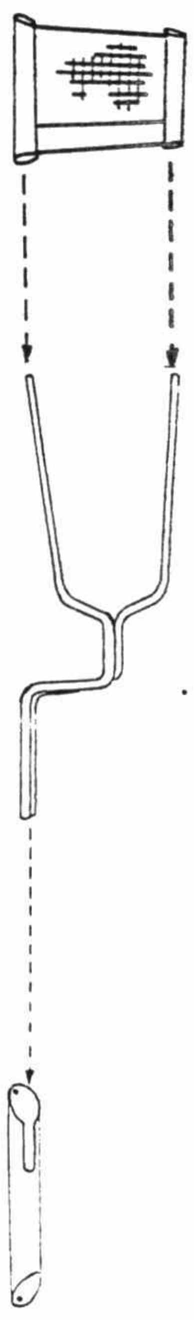


Figure 8: Moss Bag Field Holder

FIG. 9 SOWING BOARD AND PLUNGER

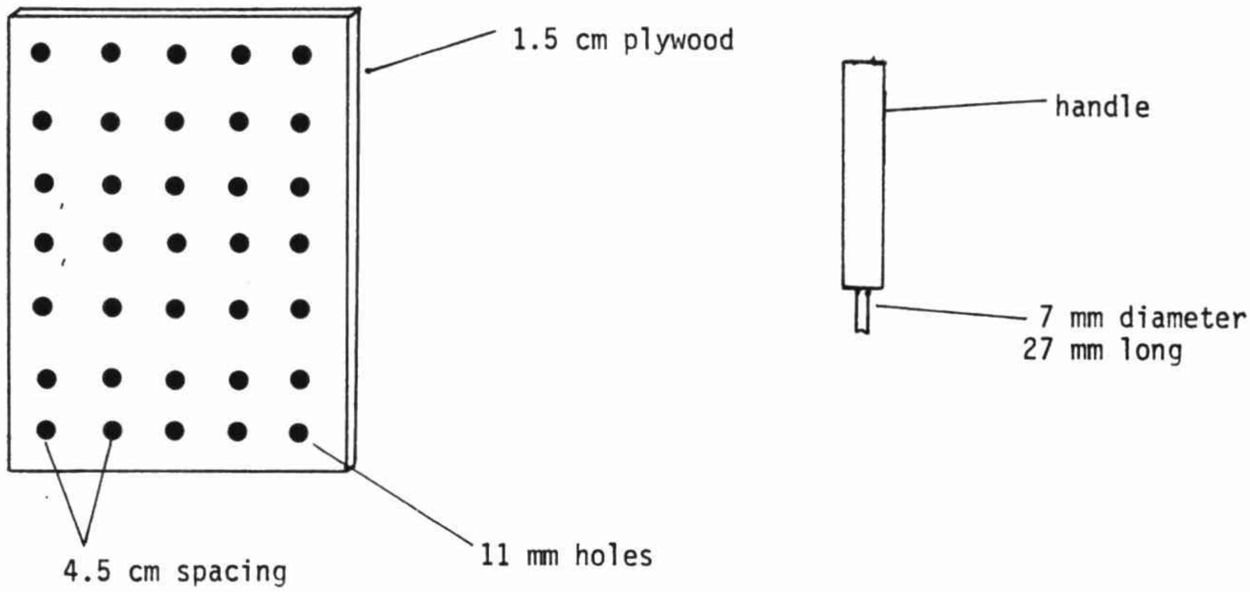
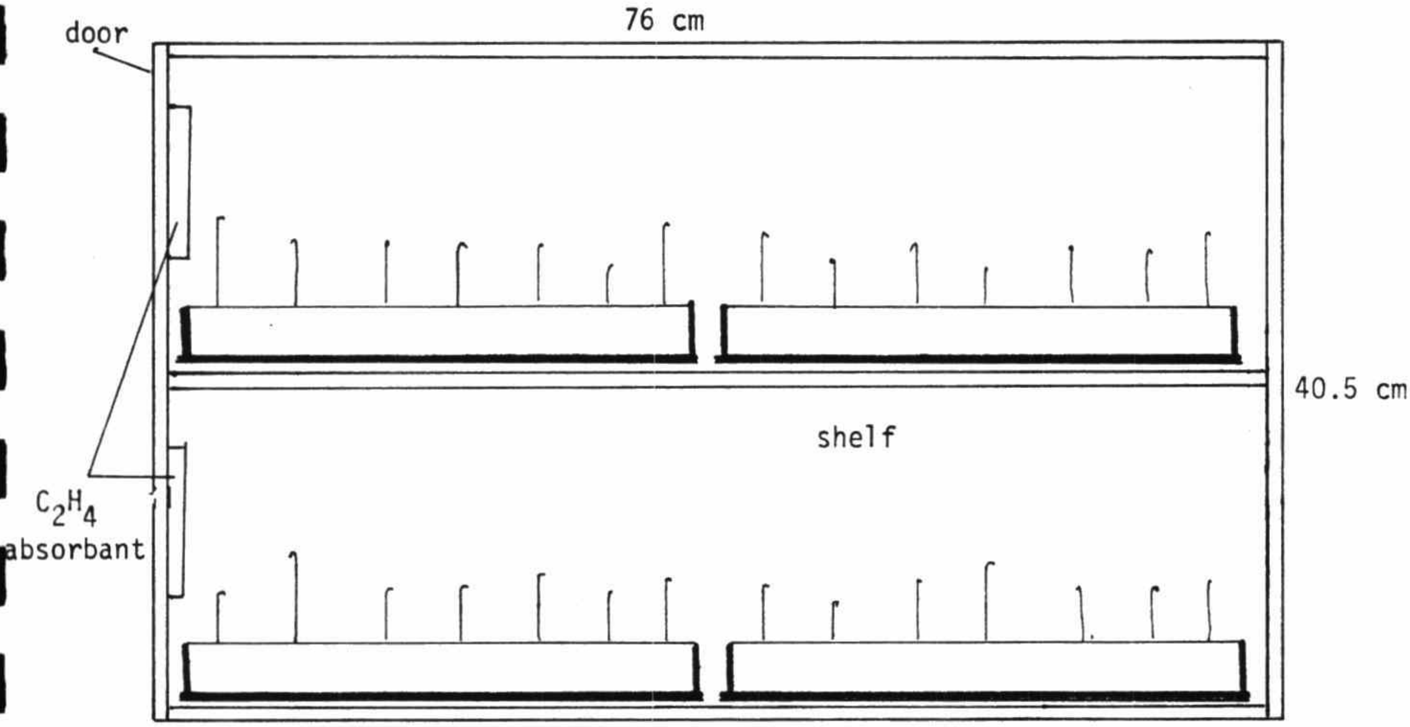
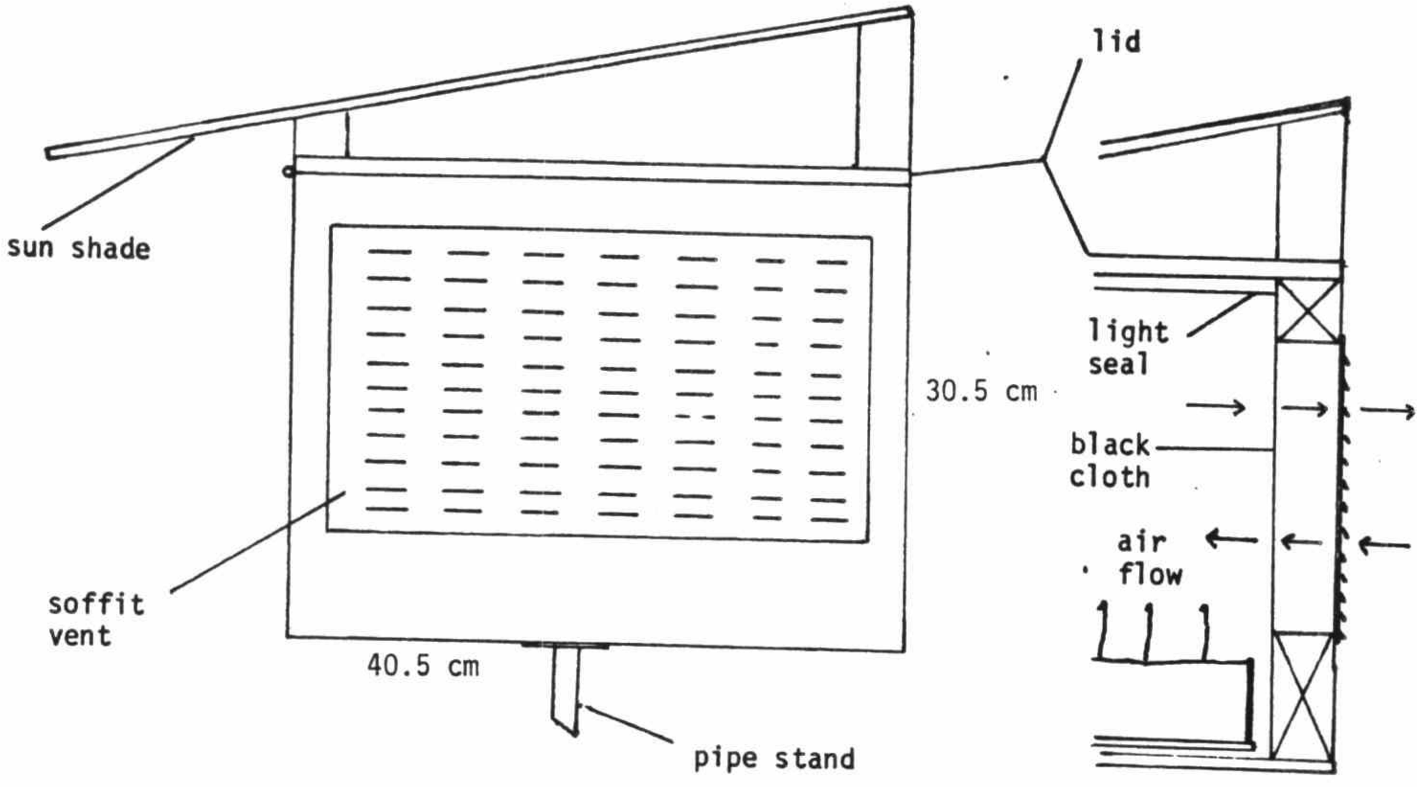


FIG. 10 TRANSFER BOX (side view)



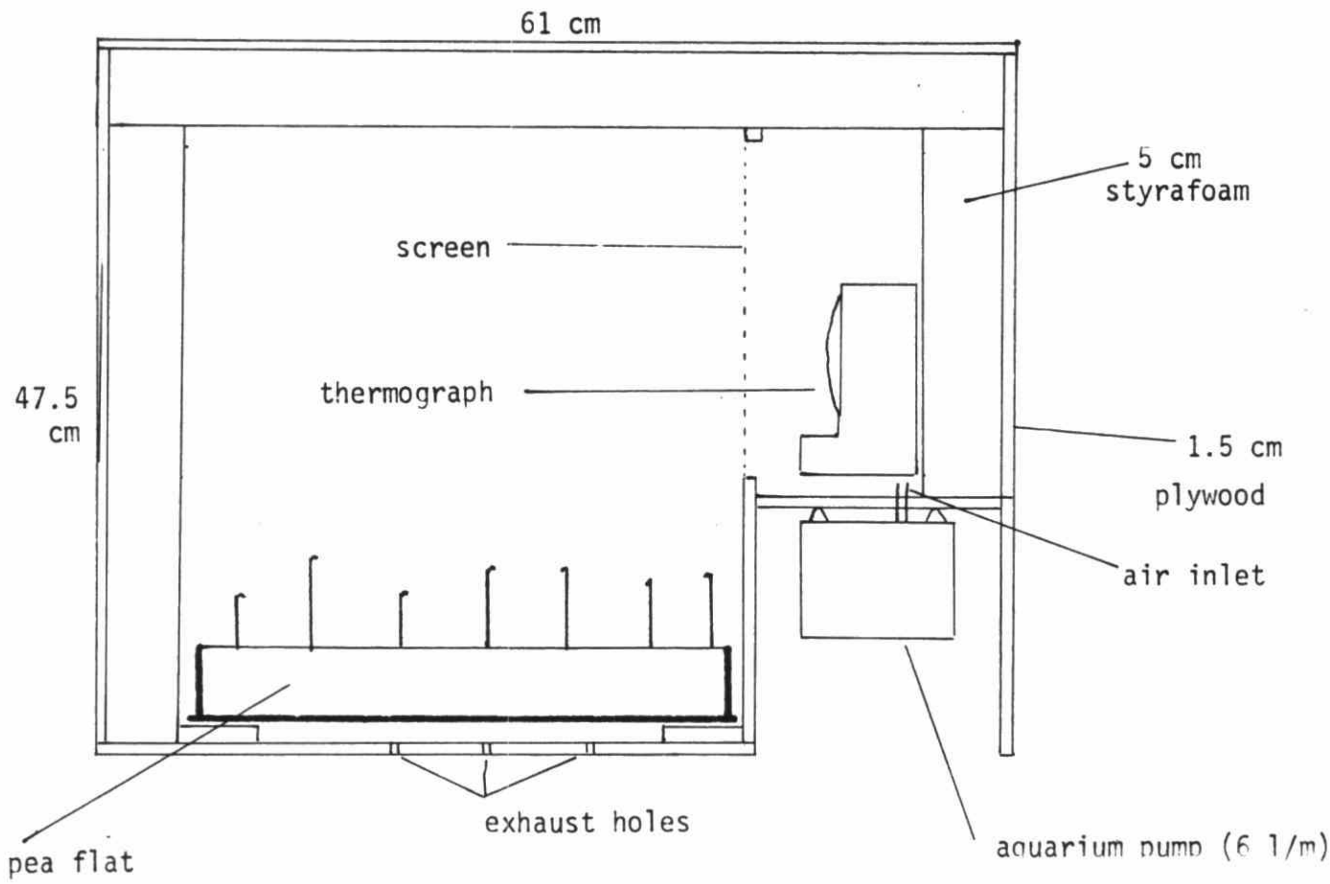
approximate size 76 X 40.5 X 70 cm (holds 8 flats)

FIG. 11 PASSIVE EXPOSURE BOX (side view and cut away view)



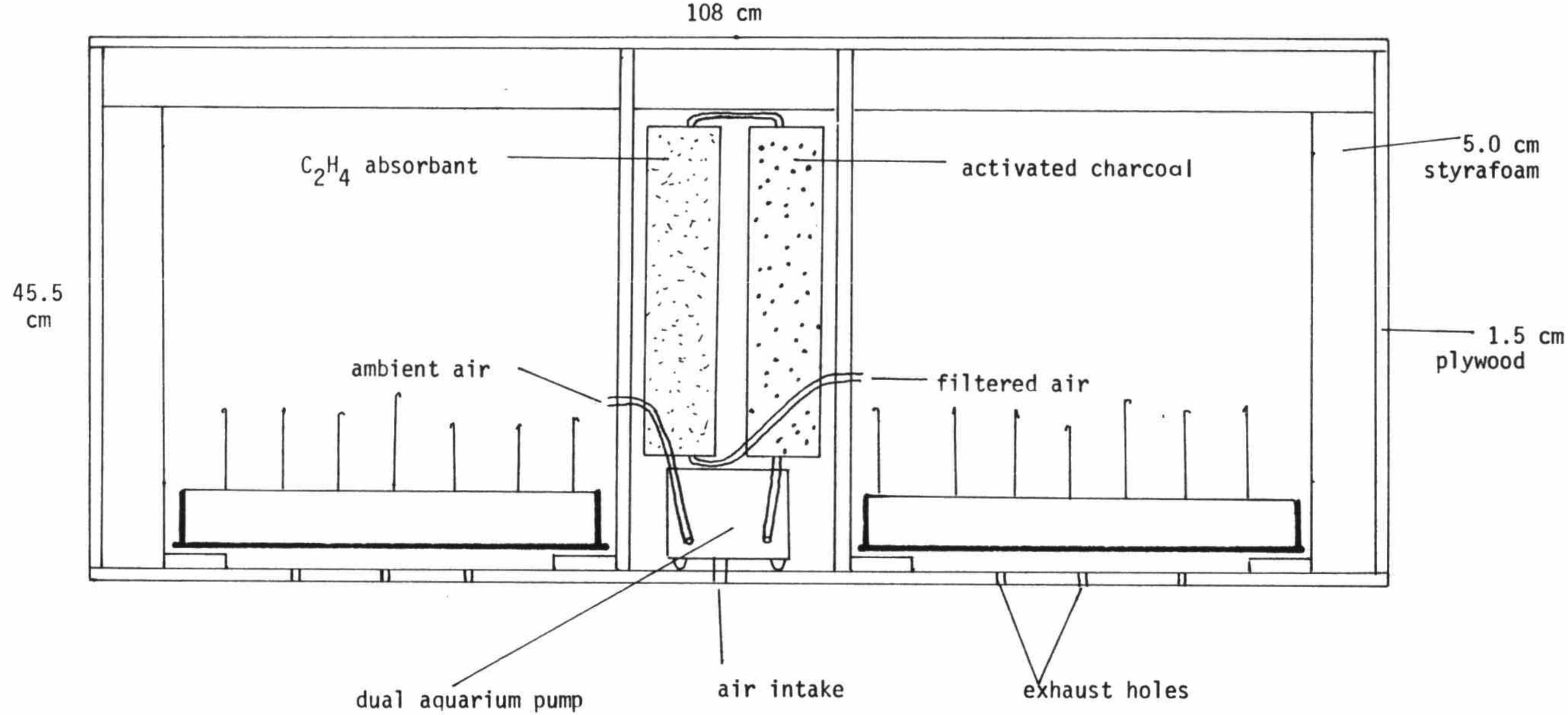
approximate size 40.5 X 30.5 X 45.5 cm

Fig. 12 ACTIVE EXPOSURE BOX (side view)



approximate size 61 X 42.5 X 47.5 cm

FIG. 12b DOUBLE ACTIVE EXPOSURE BOX (side view)



approximate size 108 X 45.5 X 42.5 cm

CONTROLLED ENVIRONMENT UNIT, PHYTOTOXICOLOGY SECTION

REQUEST FOR USE OF CONTROLLED ENVIRONMENT FACILITY

Investigator(s): ______________________________

Project title: ______________________________

Number of Fumigations: ______

Fumigation Number _____

Pollutant: O_3____, SO_2____, H_2S____, C_2H_4____, F____, Other________ (check one)

Estimated date of the fumigation ________

Number of plants to be fumigated ______ and the number of controls ______

Plant species ____________ pot size ______ and age of plants ______

Controls in the greenhouse _____ or in the growth chamber _____

Preconditioning for 24 hours yes , no (circle)

Postconditioning for 24 hours yes , no

Porometer readings required yes , no

Environmental Requirements

a. temperature day _____ ^oC , night _____ ^oC

b. humidity day _____ % , night _____ %

c. light intensity _____ uE $m^{-2}s^{-1}$ (up to 500 uE $m^{-2}s^{-1}$, or 1/4 full sunlight)

d. day length _____ hours

Pollutant Concentration and Duration of the Fumigation

a. concentration _____, _____ ppm, pphm, ppb

b. duration _____, _____, _____, _____ hours

Other Information: ______________________________

____

____

____

____

(Note: if there is more than one fumigation fill out one form for each separate fumigation using dittos where conditions are the same)

Experimental Procedures - Greenhouse Studies
Controlled Environment Unit - Phytotoxicology Section

Research ....
Reference Title: .... Complaint ....

Outline Attached: .... or Brief Description: ....

....

.... Duration ....

Design: Treatments: No. .... + Control   No. Replications ....
1 lot only .... or .... lots at intervals of ....

Container: pots .... size .... full flats .... ½ flats ....   Total No. ....

Growing Medium:
(i) Soil - Regular greenhouse mix only ....
- Special for treatments only ....   screen .... do not screen ....
- Special only ....   screen .... do not screen ....
(ii) Other - ....

Plant Species .... variety .... variety ....
.... variety .... variety ....
.... variety .... variety ....

Planting: Direct Seeding .... Transplanting .... Required No. plants per (container ...
Seed treated .... untreated .... either ....

Stage or Age for Treatment Application: ....

Cultural Conditions:

Fertilizer: normal .... omit .... special ....

Watering: Tap .... Distilled .... Other .... Special Instructions ....

.... Amounts recorded .... unrecorded ....

			Day	Night		Day	Night
Light: normal	special	Temp.	....	.....	Humidity	....	.....

Sample Collection Prior to Commencement of Study: ....
....
....
....

Data Collection During Study: ....
....
....
....

Sample Collection at Termination: ....
....
....
....

Soil retained ..... discarded .....   Plant material retained ..... discarded .....

Requested by: ....

Date initiated	completed	reported ....

CHAPTER 6: SAMPLE COLLECTION PROCEDURES

A Chemical Analysis

1 Vegetation Samples

Trees or shrubs should be sampled on the side facing (fully exposed to) the source(s) by removing as many small shoots as possible in order to properly represent the tree or shrub being sampled. That is, the shoots selected should be well distributed across the exposed side of the plant. A minimum of 10 such shoots, each representing the entire current year's growth, should be cut from each tree or shrub sampled. Evergreen foliage should be collected in a similar manner except that different years' growth should be bagged, identified and processed separately. Foliage should not be permitted to fall on barren soil or gravel surfaces during sampling, and should not be set down on these or other types of contaminated surfaces prior to bagging. More than one specimen of the same species can be sampled at each site provided each is adequately exposed to the source. Foliage should be removed from the twigs with reasonable care in order to minimize tearing. As sampling errors have been established from past years' data for most of the major study areas can be used as inference for future sampling, all foliage of the same species should be bulked to form a "composite" sample for each sampling site, and placed in a single bag with its appropriate identification number.

At the discretion of the investigator-in-charge certain modifications or additions to the above may be made:

i) In new survey areas, in areas where past surveys have revealed a high degree of variability or in areas where the data may be challenged (court cases, control orders) it is recommended that replicated (3 or more) sampling be conducted at each site with each of the replicated samples being collected as if it were a single sample (i.e. shoots placed in separate piles prior to removing leaves for each sample bag). This will permit attachment of valid statistical confidence limits (sampling error) to the sampling results;

ii) Where a question may later arise with respect to source location, an investigator-in-charge may choose to separately

sample those sides of trees or shrubs considered protected from the source. By repeating this "side facing/side away" procedure at several locations around the suspected source, a firmer case may be developed.

2 Forage Samples

The collection of forage is usually restricted to those areas where contamination of livestock feed may have occurred. At each sampling site, forage should be sampled in as random a manner as the site will permit. In an open field where such randomization is easiest, samples may be collected using predetermined co-ordinates from a random numbers table or an 'M' 'X' 'W' or 'Z' pattern which can be walked in the field. A unit of the sample is defined as having been collected each time a sampler cuts a portion of forage.

As a guide to the number of units of the sample that should be collected, reference is made to the coefficient of variation (CV = standard deviation/mean) determined from the past years' sampling for each sampling site. The table below shows the number of units of the sample that should be collected in order to achieve the stated accuracy for the known coefficient of variation. In cases where the CV is not known, a minimum of 15 units should be collected.

Number of Sample Units Required for Indicated Coefficient of Variation

Desired Accuracy of Estimate	CV 0.10	0.12	0.14	0.16	0.18	0.20	0.30	0.40	0.50
± 5%	16	23	31	41	52	64	144	256	400
± 10%	4	6	8	10	13	16	36	64	100
± 15%	2	3	4	5	6	7	16	28	44
± 20%	1	2	2	3	3	4	9	16	25

The sampling procedure with forage can be modified as in A1 (ii)

above where a high degree of intra-site variability is suspected. In this case the replicated samples should consist of a minimum of 10 units collected in separate bags during 3 different passes over the field or lawn. Forage is usually collected in a manner which will best approximate a grazing animal; that is, the top 15 cm of new growth is cut. Old, dry grass stems from the previous year's growth should be avoided, as should unpalatable weeds and sedges.

3 Soil Samples

The methodology of collection of soils is determined by the purpose of the collection. Generally, soils are collected for one or more of the following reasons:

a) Total Contamination

Contamination is assessed at the investigator-in-charge's discretion by sampling soils at the 0-5 cm depth or by multi-depth sampling (0-5, 5-10, 10-15 cm) using a standard soil core borer. Like forage samples, soil sampling is carried out in as random a manner as the site will permit using a random co-ordinate system or the "M' 'X' 'W' or 'Z' pattern described for forage. Like forage sampling, the final composite sample from each site is comprised of numerous units, a unit being defined as a single core. This number, which should not be less than 15 cores, should be maintained regardless of the site area. Where multi-depth sampling is carried out, samples from each depth are bulked separately. Neither surface leaf litter nor debris should be knowingly included in the sample. The soil core borer should be cleaned between sites. If required, replicated sampling should be conducted as for forage samples (A2).

b) Plant Available or Extractable Contamination

The sampling procedure for this type of analysis should be similar to that described for Total Contamination. The only difference is that a more meaningful value with respect to plant uptake can be obtained from samples collected from the plant root feeding zone: 0-15 cm for most crops and ornamentals. In view of the intimate relationship between soil reaction (pH) and contaminant 'availability' it is recommended that pH be recorded for all samples collected for extractable

content.

c) Fertility

Fertility samples are collected in the same manner as samples for total contamination except with respect to depth. Soils for fertility are collected in the plant root feeding zone: 0-15 cm for most crops, and ornamentals.

B Pathology Diagnosis

The following field collection procedures will ensure that all samples collected for pathological investigation are received in the best possible form for symptom examination, isolation and identification.

i) Select specimens to illustrate as completely as possible the various parts of the plant affected by the disease; whenever possible, roots, tubers, bulbs, stems, leaves, flowers and fruits should be collected.

ii) It is important that all plant material arrive at the laboratory in good condition with a completed field label and assigned number. Samples should be collected in perforated plastic bags (large or small) so as to minimize dehydration during transit and storage.

C Histology Diagnosis

The following important points are suggested to all field investigators when collecting samples for histological observation.

i) Take glass jars filled with regular FAA fixing solution (will be prepared by the Histopathologist on request) with you to the field. Plant samples can be well preserved in this way for histology study for a long time without changing cell structures. However, for observation of symptomatology, fresh samples must be collected together with the preserved samples.

ii) Select very typical specimens which represent the injury that you are investigating. Although very little plant material is required the sample should be typical. Specimens should include all varied stages

of symptoms (incipient, medium and severe) of injury observed in the field.

iii) Specimens for "control" purposes must be collected. These should include samples from healthy plants remote from the affected area.

iv) Record all relevant information on the appropriate form.

D Nematode Diagnosis

Field sampling can give some knowledge of the nematode situation in a particular area. The success of this technique will be improved by following the outline below:

i) A sample containing at least one litre of soil is required.

ii) The sampled soil should be a composite obtained from at least five sites selected throughout the affected area from the 0-20 cm depth.

iii) If roots of the injured crop are available, they must be included in the soil sample; (preferably young roots).

iv) Plastic bags tied firmly and tagged on the outside make good containers.

v) Field labels should contain all necessary information, including location and size of area or field sampled, name and variety of crop, collector's name, and a description of the symptoms.

E Herbarium Preservation

A plant may be collected for the herbarium for one of three reasons: 1. the specimen is a permanent one which is properly pressed, dried and mounted, and clearly illustrates the particular causal agent symptoms; 2. the specimen collected may be for personal reasons, may show a peculiar symptomology or may be required for a court case and it too is well pressed, dried properly and mounted, but this specimen is placed in the documentary section of the herbarium; and 3. the specimen is collected for personal reasons by the investigator

and is of no value to anyone other than the collector; less care may be taken in pressing and this plant is not mounted on herbarium paper but kept in a herbarium cabinet and discarded after one year.

The following is a guide to collecting plant material in the field to ensure good specimens for identification and for the herbarium. Complete details on pressing drying labelling and mounting are outlined in the Laboratory Manual.

i) In collecting small herbaceous plants, the whole plant should be collected including inflorescence (if present) and roots, keeping in mind the size of the herbarium sheet (30 X 45 cm).

ii) With larger plants, trees and shrubs, 25-30 cm long samples should be taken from the end of the plant or branch with several leaves intact and showing terminal and lateral buds, flowers and fruits.

iii) In collecting, care should be taken to select a good representative specimen which illustrates exactly what you want and what others will be able to identify.

iv) When collecting samples of injured plants, always include adequate material, either less injured or uninjured for positive identification of the host.

CHAPTER 7: USE OF FIELD AND LABORATORY FORMS

In order to ensure uniformity and continuity in the collection, description, identification, processing and allocation of the thousands of samples of vegetation and soil which are collected annually for laboratory examination or analysis, a number of standarized forms have been prepared for each phase of the collection, allocation, and reporting process. They have been listed below and appended for reference purposes. A short description of the purpose of each form follows.

Submission Sheet: Terrestrial Effects

This is a covering form which must accompany all submissions to the main laboratory. It shows the sample series, defines the program and sampling agency (pre-assigned codes) and identifies the individuals who are to receive copies of the results.

Request For Analysis: Terrestrial Effects

This is the form which is used in the field to completely describe each sample, assign it a field sample number, and to indicate the analytical parameters required. Because this is the only form accepted under the L.I.S. system it will accommodate all types of analytical request, regardless of the number of work stations involved. The information in the Field Data portion of the form will not be recorded in the L.I.S. but will be utilized in the Sample Information System (S.I.S.) for data retreival. Investigators should fill in as much information about the sample as possible as this is the only record of sample description on file.

In view of the complexity of the coding system which has been developed for both the Submission and Request for Analysis Forms, a separate information package has been prepared by each of the major terrestrial effects groups (i.e. Phyto, NE, NW, APIOS) and will not be included in this manual.

Phytotoxicology Field Sample Enclosure

This form is used for identification of all samples collected for herbarium, pathology, fertility, or bioassay analysis or examination. There also is provision for the allocation of other types of laboratory examination in the blank descriptive boxes. As previously stated, it is <u>essential</u> that this form be completed in detail and included with the field sample at the time of collection.

Phytotoxicology Histology Sample Enclosure

This form is intended solely for the collection of samples for histological examination. Complete information on the sampling aspects of histological collection can be found in Chapter 6, Section C.

Terrestrial Effects Station Identifier Form

This form has been designed to geographically identify all permanent sampling station locations. It must be completed for all assessment survey stations in both Phytotoxicology and APIOS programs. This information is co-ordinated by B. L. Chai who is working with the Systems Development Branch in getting the information into S.I.S storage for use in all retreival formats. As with the other L.I.S. forms complete details on the completion of this form, including the coding parameters will be included in a separate forms completion procedure by each of the major user groups.

Field Investigation Report Form

This form was prepared to assist field investigators in the submission of field activity summaries. The form must be completed for all field investigations regardless of the complexity or nature of the visit. This includes reconnaissance or plot maintenance, experimental investigations, follow-up complaint re-visits as well as the regular assessment survey or external request sample collection investigations. The original will go to the main file for a permanent record showing the details of the work performed or samples collected.

[redacted]

Min[redacted] of the Environment
Ontario

[redacted] Sh[redacted]
Terrestrial Effects

Lab. use Only [redacted] No.

From Field Sample No. | To Field Sample No. | Page | of

Sample Program Code: 0 2 0 0 5 (Prog. | Study | Pro. Act. | Sub Prog. Act.)

Lab | Pri | FD Type

Sampling Agency: 0 1 0 2 0 2 0 4 (Min. | Dn. | Br. Reg. | Sec. | Unit)

Vote | Item

Date Submitted: / / (DD MM YY)

Project/ Mun. Code | Municipal/Project | Name of Sampler | Phone

Client Code 1 | Report to (Name) | Phone | Establishment

Address | City | Province (Country) | Postal Code

– – – – – – Copies To – – – – – –

Client Code 2	Name	Phone
AR 010	Dr. S. N. Linzon	
Establishment		
Address		
City	Province (Country)	Postal Code

Client Code 3	Name	Phone
AR 004	Mr. B. L. Chai	
Establishment		
Address		
City	Province (Country)	Postal Code

Client Code 4	Name	Phone
Establishment		
Address		
City	Province (Country)	Postal Code

Client Code 5	Name	Phone
Establishment		
Address		
City	Province (Country)	Postal Code

[redacted]stry [redacted]
of the
Environment

Ontario

Request for Analysis
Terrestrial Effects

[redacted]ubm[redacted]No. [redacted]

Page ____ of ____

Phyto Field Sam. No.	Date DD MM YY	Analyze For:	Location	Sample Description	Other Allocation	Sampler Remarks
Con. Sent / Con. Miss.	Type					
Lab. Sample No.	Lab. Remarks					

Field Data SIS Type 0 7 5 (20) · Sample/Species (23) · Sam. Ty. (27) · Area Ty. (29) · Foliar Injury N C O (30) · Alloc. (36) · Conv. Fact. (38) · S. Q. (41) · Snow Sample T.D. F.D. #C (42) · Soil pH (48)

Universal (51, 53) · Transverse · Mercator (60) · (68) · T.C. (69) · N.R. (71) · G.S. (73) · A. (75) · B. (78) · C. (80)

Phyto Field Sam. No.	Date DD MM YY	Analyze For:	Location	Sample Description	Other Allocation	Sampler Remarks
Con. Sent / Con. Miss.	Type					
Lab. Sample No.	Lab. Remarks					

Field Data SIS Type 0 7 5 (20) · Sample/Species (23) · Sam. Ty. (27) · Area Ty. (29) · Foliar Injury N C O (30) · Alloc. (36) · Conv. Fact. (38) · S. Q. (41) · Snow Sample T.D. F.D. #C (42) · Soil pH (48)

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Universal (51, 53) · Transverse · Mercator (60) · (68) · T.C. (69) · N.R. (71) · G.S. (73) · A. (75) · B. (78) · C. (80)

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Con. Sent / Con. Miss.	Type					
Lab. Sample No.	Lab. Remarks					

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Universal (51, 53) · Transverse · Mercator (60) · (68) · T.C. (69) · N.R. (71) · G.S. (73) · A. (75) · B. (78) · C. (80)

Phyto Field Sam. No.	Date DD MM YY	Analyze For:	Location	Sample Description	Other Allocation	Sampler Remarks
Con. Sent / Con. Miss.	Type					
Lab. Sample No.	Lab. Remarks					

Field Data SIS Type 0 7 5 (20) · Sample/Species (23) · Sam. Ty. (27) · Area Ty. (29) · Foliar Injury N C O (30) · Alloc. (36) · Conv. Fact. (38) · S. Q. (41) · Snow Sample T.D. F.D. #C (42) · Soil pH (48)

Universal (51, 53) · Transverse · Mercator (60) · (68) · T.C. (69) · N.R. (71) · G.S. (73) · A. (75) · B. (78) · C. (80)

Ontario Ministry of the Environment

Phytotoxicology Field Sample Enclosure

Sample No.

Region	Day	Month	Year	Sampler	Ext. Request	
			19		Assess. Survey	
					Expt.	

Location (Name Address)	Injury Description
Sample/Species	
Susp. Casual Agent	

HERB		PATH		COUNT	Fert	Bioas	Cryst		
Main Collect		DISEASE INSECT NEMA	Fungi						
Docum.			Bact.						
Other		COMPLETE EXAM.	Actin						

1117 2/82

Ontario Ministry of the Environment

Phytotoxicology Histology Sample Enclosure

Sample No.	E.Req	
	A.Sur	
	Expt.	

Date:	Sample Species:	Fresh	
Location:		F.A.A.	
		Region	

Field Symptom	Histo. work requested:		
	complete examination		
	causal agent diagnosis		
	photo of:	symptom	
		tissue damage	
		surf. depos.	
Causal agent suspected:	Other		
	gen. report	detailed report	no report
Investigator-in-charge			

0010 3/81

Ministry of the Environment
Ontario

Terrestrial Effects – Station Identifier Form

Region [ ] . . . .

Source/Study Name [| |] . . . .

Source Address/Area . . . .

Permanent Station Identifier Number [| |]

Distance and Direction from Source . . . .

Station Address/Location . . . .

U.T.M.

Station Previously Identified as: . . . . from 19 . . to and including 19 . .

. . . . from 19 . . to and including 19 . .

. . . . from 19 . . to and including 19 . .

Sketch Showing Location of All Samples Collected (Show N)

Form Prepared by: . . . . on . . . . 19 . .

Form Revised by: . . . . on . . . . 19 . .

Nature of Revisions

Ministry of the Environment
Ontario

Field Investigation Report Form

PHYTOTOXICOLOGY SECTION
AIR RESOURCES BRANCH

External Request

No. Complainants

Name _______________

Address _______________

____

(additional names in Remarks)

Region

Alleged Source _______________

Assessment Survey

Source _______________

No. Stations Visited

Location _______________

____

Region

Experimental

Proj. Title _______________

Region

Investigation Date(s) _______________ 19 __ Sent in ______ by _______________

PS-2 Field Sample No.s From _______________ to _______________ Samples not Taken

Allocation of Samples Collected: (L.I.S. Submission Sheets Attached)

Lab.	Type and No. of Samples			Number of Chemical Analyses Requests
Inorg.	Veg.		Chemical	
	Soil		No.	
Org.	Veg.		Chemical	
	Soil		No.	
Phys.	Veg.		Chemical	
	Soil		No.	
Pest.	Veg.		Chemical	
	Soil		No.	

Other Requests	No. Samples	PS-2 Field Sample Numbers
Herb		
Path		
Hist		

Brief Description of Work Performed and Observations:

More Detailed Description Attached

Remarks:

Total Man Hours _______________

Investigator-in-Charge _______________ Assisted by _______________

Copies to: _______________, _______________, _______________, _______________

MOE 1626/80

CHAPTER 8: LEGAL ASPECTS OF SAMPLE COLLECTION

Sample collection in cases where legal action may arise requires special care due to the influence this sampling may have on case outcome. In general, the sampling methods that have been described previously may be used; however, the following additional points and techniques should be fully read and understood before any samples are taken.

i) The soil area or plant species to be sampled should be carefully examined so that the investigator-in-charge will be completely familiar with the overall geographic location of the sample. Preparation of a sketch map showing the location of the samples is recommended.

ii) The investigator-in-charge should obtain prior knowledge of exactly what type of contamination he/she is dealing with and sample accordingly with respect to correct containers and processing requirements.

iii) As legal samples must be analyzed in duplicate, it is recommended that at least twice the normal sample volume be collected.

iv) Samples should be collected from as many locations as necessary to effectively rule-out contamination from other sources in the area; this will include the collection of control samples to establish background contaminant concentrations for similar soil types or plant species in at least one area remote from the influence of the alleged source.

v) It is preferable but not essential that the actual sampling be performed with the assistance of a witness who is willing to sign a witness affidavit and appear in court if necessary.

vi) All necessary forms and paper-work should be completed in detail and cross-checked to ensure that the sample numbers coincide with the material collected.

vii) As the investigator-in-charge must be able to swear that the samples were in his possesssion and control before signing them into the processing laboratory, the following procedures must be followed:

- the vehicle used to transport the samples must be locked whenever the investigator-in-charge is visibly removed from it

- on overnight investigations the samples must be kept either in the locked vehicle or, by special arrangement, in a cold room or refrigerator which can be locked with a M.O.E lock and key.

viii) Once the samples have been signed into the Processing Laboratory, it is the responsibility of the laboratory supervisor to ensure that they are stored in a locked area and processed and delivered promptly to the analytical laboratory using the locked box procedure.

CHAPTER 9: APPENDIX

A Metric Conversion Factors

To Convert		Into	Multiply by
		A	
acres		hectares	.4047
acres		sq feet	43560.0
acres		sq meters	4047.0
acres		sq miles	1.562×10^{-3}
acres		sq yards	4840.0
		B	
barrels	(oil)	gallons	42.0
barrels	(dry)	cu inches	7056.0
barrels	(dry)	bushels	3.281
barrels	(dry)	quarts (dry)	105.0
barrels	(dry)	cu meters	0.1156
bushels	(U.S.)	cu feet	1.2445
bushels	(Imp.)	cu feet	1.2842
bushels	(U.S.)	cu inches	2150.4
bushels	(Imp.)	cu inches	2219.36
bushels	(U.S.)	cu meters	0.03524
bushels	(Imp.)	cu meters	0.03637
bushels	(U.S.)	liters	35.24
bushels	(Imp.)	liters	36.37
bushels		quarts (dry)	32.0
bushels	(U.S.)	bushels (Imp.)	0.969
bushels	(Imp.)	bushels (U.S.)	1.032
		C	
centimeters		inches	0.3937
centimeters		millimeters	10.0
cu centimeters		liters	0.001

cu centimeters	cu inches	0.06102
cu feet	bushels	0.8036
cu feet	cu inches	1728.0
cu feet	cu meters	0.02832
cu feet	gallon (U.S.)	7.4805
cu feet	gallon (Imp.)	6.2286
cu feet	liters	28.32
cu inches	cu centimeters	16.39
cu inches	cu feet	5.787×10^{-4}
cu inches	cu meters	1.639×10^{-5}
cu inches	gallons (U.S.)	4.329×10^{-3}
cu inches	gallons (Imp.)	3.605×10^{-3}
cu inches	liters	0.01639
cu meters	bushels (U.S.)	28.38
cu meters	bushels (Imp.)	27.50
cu meters	cu feet	35.31
cu meters	cu inches	61023.0
cu meters	gallons (U.S.)	264.2
cu meters	gallons (Imp.)	220.17
cu meters	liters	1000.0

D

dekagrams	grams	10.0
dekaliters	liters	10.0

F

feet	centimeters	30.48
feet	kilometers	3.048×10^{-4}
feet	meters	0.3048
feet	millimeters	304.8
feet	miles	1.894×10^{-4}

G

gallons (U.S.)	cu centimeters	3785.0
gallons (Imp.)	cu centimeters	4546.0
gallons (U.S.)	cu feet	0.1337
gallons (Imp.)	cu feet	0.1605
gallons (U.S.)	cu inches	231.0
gallons (Imp.)	cu inches	277.42
gallons (U.S.)	cu meters	3.785×10^{-3}
gallons (Imp.)	cu meters	4.546×10^{-3}
gallons (U.S.)	ounces (U.S.)	128.0
gallons (Imp.)	ounces (Imp.)	160.0
gallons (U.S.)	liters	3.785
gallons (Imp.)	liters	4.546
gallons (U.S.)	gallons (Imp.)	0.83267
gallons (Imp.)	gallons (U.S.)	1.20095

H

hectares	acres	2.471
hectares	sq feet	1.076×10^{5}
hectograms	grams	100.0
hectoliters	liters	100.0
hectometers	meters	100.0

I

inches	centimeters	2.54
inches	meters	2.54×10^{-2}
inches	miles	1.578×10^{-5}
inches	millimeters	25.4
inches	yards	2.778×10^{-2}

K

kilograms	grams	1000.0
kilograms	pounds (Avoir)	2.205

kilograms	pounds (troy)	2.679
kilograms	tons (long)	9.842×10^{-4}
kilograms	tons (short)	1.102×10^{-5}
kilometers	centimeters	10^5
kilometers	feet	3281.0
kilometers	inches	$3,937 \times 10^4$
kilometers	meters	1000.0
kilometers	miles	0.6214
kilometers	millimeters	10^6
kilometers	yards	1094.0
knots	kilometer/hr	1.8532

L

liters	bushels (U.S. dry)	0.02838
liters	bushels (Imp. dry)	0.02749
liters	cu centimeters	1000.0
liters	cu feet	0.03531
liters	cu inches	61.02
liters	cu meters	0.001
liters	gallons (U.S.)	0.2642
liters	gallons (Imp.)	0.220

M

meters	centimeters	100.0
meters	feet	3.281
meters	inches	39.37
meters	kilometers	0.001
meters	miles	6.214×10^{-4}
meters	millimeters	1000.0
meters	yards	1.094
micrograms	grams	10^{-6}
microliters	liters	10^{-6}
microns	meters	10^{-6}

miles	feet	5280.0
miles	inches	6.336×10^4
miles	kilometers	1.609
miles	meters	1609.0
miles	yards	1760.0
milligrams	grains	0.0154
milligrams	grams	0.001
milliliters	liters	0.001
millimeters	centimeters	0.1
millimeters	meters	0.001

O

ounces (avoir.)	grains	437.5
ounces (troy)	grains	480.0
ounces (avoir.)	grams	28.35
ounces (troy)	grams	31.103
ounces (avoir.)	pounds (avoir.)	0.0625
ounces (troy)	pounds (troy)	0.0833
ounces (avoir.)	ounces (troy)	0.9115
ounces (troy)	ounces (avoir.)	1.097
ounces (U.S. fl.)	gallons (U.S.)	7.8125×10^{-3}
ounces (U.S. fl.)	ounces (Imp.)	1.041
ounces (Imp. fl.)	gallons (Imp.)	6.25×10^{-3}
ounces (Imp. fl.)	ounces (U.S.)	0.961
ounces (U.S. fl.)	cu inches	1.805
ounces (Imp. fl.)	cu inches	1.734
ounces (U.S. fl.)	liters	0.02957
ounces (Imp. fl.)	liters	0.0284
ounces (U.S. fl.)	cu centimeters	29.57
ounces (Imp. fl.)	cu centimeters	28.4

P

pints (dry)	cu inches	33.6
pints (dry)	cu centimeters	550.7

pints (U.S. liq.)	cu centimeters	473.2
pints (Imp. liq.)	cu centimeters	567.8
pints (U.S. liq.)	cu inches	28.87
pints (Imp. liq.)	cu inches	34.64
pints (U.S. liq.)	gallons (U.S.)	0.125
pints (Imp. liq.)	gallons (Imp.)	0.125
pints (U.S. liq.)	liters	0.4732
pints (Imp. liq.)	liters	0.5678
pounds (avoir.)	grams	453.6
pounds (troy)	grams	373.24
pounds (avoir.)	ounces (avoir.)	16.0
pounds (troy)	ounces (troy)	12.0
pounds (avoir.)	pounds (troy)	1.21528
pounds (troy)	pounds (avoir.)	0.82286

Q

quarts (U.S. liq.)	cu centimeters	946.4
quarts (Imp. liq.)	cu centimeters	1136.0
quarts (U.S. liq.)	cu feet	0.03342
quarts (Imp. liq.)	cu feet	0.04010
quarts (U.S. liq.)	cu inches	57.75
quarts (Imp. liq.)	cu inches	69.30
quarts (U.S. liq.)	gallons (U.S.)	0.25
quarts (Imp. liq.)	gallons (Imp.)	0.25
quarts (U.S. liq.)	liters	0.946
quarts (Imp. liq.)	liters	1.136

R

rods	meters	5.029

S

sq centimeters	sq feet	1.076×10^{-3}
sq centimeters	sq inches	0.155
sq centimeters	sq meters	0.0001

sq feet	sq centimeters	929.0
sq feet	sq inches	144.0
sq feet	sq meters	0.0929
sq feet	sq yards	0.1111
sq inches	sq centimeters	6.452
sq inches	sq feet	6.944×10^{-3}
sq inches	sq millimeters	645.2
sq kilometers	acres	247.1
sq kilometers	sq centimeters	10^{10}
sq kilometers	sq feet	10.76×10^{6}
sq kilometers	sq meters	10^{6}
sq kilometers	sq miles	0.3861
sq kilometers	sq yards	1.196×10^{6}
sq meters	acres	2.471×10^{-4}
sq meters	sq centimeters	10^{4}
sq meters	sq feet	10.76
sq meters	sq inches	1550.0
sq meters	sq yards	1.196
sq miles	acres	640.0
sq miles	sq kilometers	2.59
sq miles	sq meters	2.59×10^{6}
sq miles	sq yards	3.098×10^{6}
sq millimeters	sq centimeters	0.01
sq yards	acres	2.066×10^{-4}
sq yards	sq feet	9.0
sq yards	sq meters	0.8361

T

temperature (^{o}C)	temperature (^{o}F)	9/5 + 32
temperature (^{o}C) + 273	absolute temperature (^{o}C)	1.0
temperature (^{o}F) + 460	absolute temperature (^{o}F)	1.0

temperature (^{o}F) - 32	temperature (^{o}C)	5/9
tons (long)	kilograms	1016.0
tons (long)	pounds (avoir.)	2240.0
tons (long)	tons (short)	1.12
tons (long)	tonnes (metric)	1.016
tonnes (metric)	kilograms	1000.0
tonnes (metric)	pounds (avoir.)	2205.0
tons (short)	kilograms	907.2
tons (short)	pounds (avoir.)	2000.0
tons (short)	tons (long)	0.893
tons (short)	tonnes (metric)	0.9072
tonnes (metric)	tons (long)	0.984
tonnes (metric)	tons (short)	1.102
tons (capacity)	cu meters	2.8307

Y

yards	centimeters	91.44
yards	kilometers	9.144×10^{-4}
yards	meters	0.9144
yards	millimeters	914.4

APPENDIX B

Ontario

Ministry
of the
Environment

PROCEDURE TO FOLLOW REGARDING INVESTIGATION AND NEGOTIATION OF CONTAMINANT DAMAGE TO VEGETATION AND LIVESTOCK CLAIMS

The Environmental Protection Act has made provision for the investigation of suspected cases of injury or damage to vegetation or livestock by a contaminant which may result in an economic loss.

Provision has been made also for the mediation of damage claims by a Board of Negotiation consisting of two or more members appointed by the Lieutenant Governor in Council, should the loss be the result of injury or damage caused by a contaminant.

The following procedure must be followed in order to have access to the provisions of the Act.

1. If it is suspected that a contaminant is causing or has caused injury or damage to vegetation or livestock, which may result in economic loss, the complainant must, within 14 days after the injury or damage becomes apparent, request an investigation. His request should be made to the Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section, 880 Bay Street, Toronto, Telephone 965-4516. If the request is made by telephone, it should be confirmed by letter.

2. The Ministry of the Environment will conduct an investigation, sometimes in conjunction with specialists from other government ministries.

3. In order to have subsequent access to the Board of Negotiation the complainant must notify the owner or operator of the alleged source of the contaminant of

. . .continued/

of the location of the damaged vegetation or livestock, or agree to have his name and address provided to the alleged source by the Ministry of the Environment. It is also necessary for the complainant to permit the owner or operator of the alleged source of the contaminant to enter his property to inspect the injury or damage and to take samples for testing and examination.

4. After the Ministry of the Environment has conducted its investigation a report is sent to the complainant and to the owner or operator of the alleged source of the contaminant outlining the extent of the injury or damage.

5. Assuming that the investigation defines the cause of the injury or damage as a contaminant and indicates the source, the two parties should attempt to make a private settlement.

6. If a mutually acceptable settlement cannot be arrived at, the claimant can obtain the services of the Board of Negotiation by notifying the Ministry of the Environment, Toronto, and the owner of the alleged source of the contaminant the monetary amount of his claim within a reasonable time after it can be determined.

7. If the two parties are not able to reach a private settlement within 30 days after notice of the claim has been given to the Ministry of the Environment, either party may serve notice of negotiation upon the other party and request that the Board of Negotiation intervene.

8. The Board of Negotiation will then meet with both parties and in an informal manner proceed to negotiate a settlement of the claim. This procedure shall be without prejudice to any subsequent proceedings.

APPENDIX C

A KEY TO PLANT-NUTRIENT DEFICIENCY SYMPTOMS

SYMPTOMS	ELEMENT DEFICIENT
A. Older or lower leaves of plant mostly affected; effects localized or generalized.	
B. Effects mostly generalized over whole plant; more or less drying or firing of lower leaves; plant light or dark green.	
C. Plant light green; lower leaves yellow, drying to light-brown color; stalks short and slender if element is deficient in later stages of growth.	Nitrogen
CC. Plant dark green, often developing red and purple colors; lower leaves sometimes yellow, drying to greenish brown or black color; stalks short and slender if element is deficient in later stages of growth.	Phosphorus
BB. Effects mostly localized; mottling or chlorosis with or without spots of dead tissue on lower leaves; little or no drying up of lower leaves.	
C. Mottled or chlorotic leaves, typically may redden, as with cotton; sometimes with dead spots; tips and margins turned or cupped upward; stalks slender.	Magnesium
CC. Mottled or chlorotic leaves with large or small spots of dead tissue.	
D. Spots of dead tissue small, usually at tips and between veins, more marked at margins of leaves; stalks slender.	Potassium
DD. Spots generalized, rapidly enlarging, generally involving areas between veins and eventually involving secondary and even primary veins; leaves thick; stalks with shortened internodes.	Zinc
AA. Newer or bud leaves affected; symptoms localized.	
B. Terminal bud dies, following appearance of distortions at tips or bases of young leaves.	

SYMPTOMS	ELEMENT DEFICIENT
C. Young leaves of terminal bud at first typically hooked, finally dying back at tips and margins, so that later growth is characterized by a cut-out appearance at these points; stalk finally dies at terminal bud.	Calcium
CC. Young leaves of terminal bud becoming light green at bases, with final breakdown here; in later growth, leaves have become twisted; stalk finally dies back at terminal bud.	Boron
BB. Terminal bud commonly remains alive; wilting or chlorosis of younger or bud leaves with or without spots of dead tissue; veins light or dark green.	
C. Young leaves permanently wilted (wither-tip effect) without spotting or marked chlorosis; twig or stalk just below tip and seedhead often unable to stand erect in later stages when shortage is acute.	Copper
CC. Young leaves not wilted; chlorosis present with or without spots of dead tissue scattered over the leaf.	
D. Spots of dead tissue scattered over the leaf; smallest veins tend to remain green, producing a checkered or reticulating effect.	Manganese
DD. Dead spots not commonly present; chlorosis may or may not involve veins, making them light or dark green in color.	
E. Young leaves with veins and tissue between veins light green in color.	Sulphur
EE. Young leaves chlorotic, principal veins typically green; stalks short and slender.	Iron